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SPINAL CORD

BY

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PREFACE TO THE THIRD EDITION.

THE following introduction to the study of the Symptoms and Diagnosis of the Diseases of the Spinal Cord, is founded on an address, delivered in October, 1879, to the Members of the Medical Society of Wolverhampton.

The third edition has been carefully revised; additions have been made in many places; and a section has been added on the diagnosis of "functional" from organic disease.

The first edition has been translated into French by Dr. Oscar Jennings, and the second into Russian by M. Zatchek.

QUEEN ANNE STREET, LONDON,
December, 1883.

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THE

DIAGNOSIS OF DISEASES OF THE SPINAL CORD.

IN the following pages an attempt is made to give an outline of the Symptoms and Diagnosis of Diseases of the Spinal Cord, with especial reference to those points on which modern investigation has added to the knowledge that is current in the profession. In order to make a description of these points useful, it is necessary to include them in a general outline of the subject, in which they may take their proper place.

Our knowledge of the symptoms of these diseases is in advance of our therapeutic power. But the study of diagnosis must not, on that account, be undervalued. Even for practical purposes our diagnostic knowledge needs to be ample and exact. A very superficial study of practical medicine will show that much diagnosis, which is of no direct avail for treatment, is essential for the diagnosis which enables us to treat successfully. Of all organs there are some diseases for which we can do little, there are others for which we can do much; but unless we are able accurately to distinguish the diseases of each class, we shall often fail to apply our skill where it would be effective. Moreover, the diagnosis is easy in some cases; while in others it is most difficult. The diagnostic knowledge which is superfluous in the one is essential in the other.

There is another reason why a general survey of the elements of the diagnosis of diseases of the spinal cord may be useful. In systematic treatises, types of disease are described. But the mutual relations of all parts of the nervous system are intricate, and its morbid states are correspondingly complex. Cases which conform to types are rare, and the untypical cases are often puzzling, and can only be understood by a clear conception of the general principles of diagnosis.

The first question in the diagnosis of diseases of the spinal cord is whether the symptoms are due to organic disease or to merely functional derangement. But although this is the first question in any case, the answer to it depends on the presence or absence of the signs of organic disease; this point in diagnosis cannot, therefore, be considered until we have discussed the character and significance of those signs. It is, however, important to note, at the outset, as a rule of cardinal importance, that the presence of a cause of functional derangement is not, in itself, sufficient ground for diagnosis. All signs of organic disease must be searched for and excluded, before the presence of the causes of functional disease is admitted as evidence. It is clear that, if there are any signs of organic disease, the existence of the causes of functional disease is of no significance whatever. Hence the importance of knowing accurately all the signs of organic disease, even those which are minute and may seem superfluous.

The causes of functional derangement frequently co-exist with organic disease. Hysterical symptoms, for instance, are often present in the subjects of organic disease in all parts of the nervous system. There are two reasons for this. Many organic diseases are the result of an inherited neuropathic disposition, which may also cause hysteria. Further, the damage from organic disease often affects very widely the nutrition and function of the nervous system, and thus leads to the manifestations of hysteria, in addition to the symptoms of the organic disease. Hysterical symptoms are often obtrusive, for instance, in cases of tumour of the brain. Hence the existence of such symptoms constitutes, alone, small evidence that a given disease is merely functional. It may seem superfluous to dwell upon so obvious a point, but I have often known cases to be regarded as purely hysterical, when the plainest signs of organic disease were to be found, if looked for; and this merely because the patient presented manifestations of hysteria. The same thing is true of other causes of functional derangement, and it is true of the simulation of disease. Circumstances suggestive of malingering should be allowed no weight until the signs of organic disease are proved to be absent. Not rarely the neglect of this obvious rule has led to cruel injustice. When we think that symptoms are simulated, we should always look on our diagnosis, as well as on the patient, with suspicion, and be very sure that we are right, before we act on our opinion.

If there is evidence of the existence of organic disease, we have to ascertain its seat and nature—to make, that is, the anatomical and pathological diagnosis. It is of importance to keep these two points distinct in our minds. Their confusion is a fertile source of error in diagnosis. It is true that certain parts of the nervous system are frequently the seat of certain morbid processes; but if we infer that because this or that region is diseased, the morbid process is of this or that character, we make a pathological diagnosis from anatomical facts; and such a diagnosis will, not rarely, be erroneous. It is true we have sometimes to use this mode of reasoning: in the absence of other evidence, or as corroborating other evidence, it is legitimate and useful; but it is only thus to be used, and always with full recognition of its character and uncertainty. As an instance, we may take the case of inco-ordination of movement of the legs—locomotor ataxy. This indicates disease of a certain part of the spinal cord. In the majority of cases the disease in this region is of a certain character; but in some, the symptoms being the same, the nature of the disease is different; and to infer the character of the morbid process, in the latter case, from the symptoms present, would lead us, not only to a wrong diagnosis, but to an erroneous prognosis and unwise treatment.

It is to be remembered, then, that we can only infer from the symptoms present in a case at a given time—the *seat* of the disease. To learn its *nature* we have to study the way in which the symptoms came on, and any associated conditions which may be present.

I have put this rule thus absolutely because it is one of great importance, often overlooked. There are, however, certain exceptions to it, especially the facts that pain, acute spasm, and sloughing of the skin are sometimes (not always) signs of an *irritative* lesion. Even here, however, the exception is rather apparent than real; for it is the acuteness of these symptoms, rather than their mere occurrence, which is of *pathological* import.

We will consider first, then, the elements of the anatomical diagnosis, the signs which indicate the seat of the disease—"localization," as it is the fashion to term it—and afterwards glance at the elements of the pathological diagnosis; that is, the symptoms which indicate the nature of the morbid process.

We can only learn the significance of symptoms by ascertaining their nature and origin—what they are and why they are. Hence our study of diagnosis must consist to a large extent in what may be termed symptomatic pathology. The symptoms of disease are alterations of healthy function, and much of our symptomatic pathology is, literally, perverted physiology. We must, accordingly, in the first place, have a clear conception of such points in the structure and normal function of the spinal cord, as may enable us to understand the origin of the symptoms of its diseases.

I.—MEDICAL ANATOMY OF THE SPINAL CORD.

The position of the cord, and of the origins of the nerves, in relation to the bony canal in which it lies, is the first important point which we have to consider. It will be remembered that the cord does not, in the adult, extend through the entire length of the spinal canal. It ends opposite the 1st lumbar vertebra, or opposite the interval between the 1st and 2nd lumbar vertebræ. Hence the various pairs of nerves (except the highest) do not arise from the cord opposite the vertebræ at which they leave the canal, and after which they are named, but at a higher level. The difference between the level of origin and of exit, slight in the cervical region, increases as we descend the cord, until, as you know, in the cauda equina, the lowest nerves have a very long course from the end of the cord to their foramina. It is important to know what nerves correspond in their origin with a given part of the vertebral column, because the cord often suffers secondarily to disease or injury of the bones. The relation is rendered more complex by the fact that the vertebral spines, which alone we can feel, and which constitute, therefore, our localizing guides, do not correspond in all parts to their vertebræ. Since these points are important in diagnosis, and are not adequately described in any English work, I have prepared a diagram (Fig. 1) showing the average relations of the spines to the bodies of the vertebræ, and of both to the origins of the spinal nerves. The tips of the cervical spines correspond nearly to the lower borders of the corresponding vertebræ. Each of the upper three dorsal spines corresponds nearly to the upper border of the body of the vertebra below. From the 4th to the 8th dorsal, each spine corresponds to the middle of the body of the vertebra below. The 9th, 10th, and 11th spines slope less, and their tips again correspond to the upper borders of the next vertebræ, while the rest of the spines are opposite the bodies of their own vertebræ.

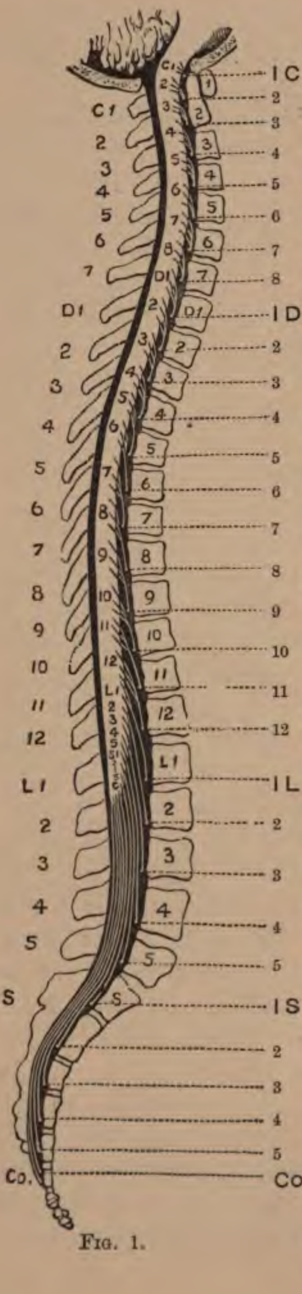

FIG. 1.

What is the relation of the spines to the nerve origins?* The first three cervical spines are opposite the origins of the 3rd, 4th, and 5th cervical nerves. The 6th and 7th pairs arise opposite the intervals between the 4th and 5th, and the 5th and 6th, cervical spines respectively. The 6th cervical spine corresponds to the origin of the 8th cervical nerve, and the 7th cervical spine to the first dorsal nerve. The first four dorsal spines vary. The 1st spine corresponds to the interval between the 2nd and 3rd pairs, or to the origin of the 3rd pair. The 2nd spine is between the 3rd and 4th pairs, or opposite the 4th pair. The 3rd spine is opposite the 5th, or the interval between the 5th and 6th pairs. The 4th spine is opposite the lower part of the origin of the 6th pair, or even below it. The 5th spine always corresponds to the origin of the 7th pair; the 6th spine to the 8th pair; the 7th to the 9th pair; the 8th to the upper part of the 10th pair; the 9th to the

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* The only recorded observations on this point are those of Nuhn and Jadelot. The facts stated in the text are partly the results of a fresh examination of the relations, kindly made for me by Mr. V. Horsley, Demonstrator of Anatomy in University College.

11th pair, and the 10th to the 12th pair. The 1st lumbar nerve arises opposite the 11th dorsal spine; the 2nd lumbar opposite the interval between the 11th and 12th spines; the 3rd and 4th opposite the 12th spine; the 5th dorsal and 1st sacral opposite the interval between the 12th dorsal and 1st lumbar spines, while the remaining sacral nerves arise nearly opposite the 1st lumbar spine.

I need not describe in detail the relations of the origins of the nerves to the bodies of the vertebræ, since they may be inferred from the facts I have given, or ascertained by a reference to the diagram.

Thus the cervical enlargement of the cord, which ends at the origin of the 1st dorsal nerves, corresponds nearly to the bodies and spines of the cervical vertebræ, while the lumbar enlargement, which commences at the 12th dorsal nerves, corresponds to the bodies of the 11th and 12th dorsal and 1st lumbar vertebræ, and to the lower three dorsal and 1st lumbar spines.

We may next consider, briefly, the general structure of the cord, seen in a transverse section, such as is represented in the accompanying diagram (Fig. 2). It is divided into two halves by the anterior and posterior fissures, *af.* and *pf.* The latter is rather a septum than a fissure. The position of each is marked by a depression in the surface. In addition there are two other depressions, one where the posterior nerve-roots enter (*pr.*); another (at *s.*) about midway between this and the posterior fissure. The two "fissures" do not meet, being separated by the commissure which connects the two halves. The grey matter, in each half of the cord, is surrounded by the white substance, and is divided into two portions, or "cornua." The anterior cornu (*ac.*) varies much in size and shape in different parts of the cord, being much larger in the cervical and lumbar enlargements than in the dorsal region. It does not come to the surface; the anterior nerve-roots (*ar.*) reach it by passing through the anterior column. The posterior cornu (*pc.*, Fig. 2) is much smaller, and comes almost up to the surface at the depression (*pr.*) where the posterior nerve-roots enter. It is much larger in the lumbar enlargement than in the cervical and dorsal regions. The white substance is composed of nerve-fibres running vertically; and since these end at different levels, the white substance lessens in amount from above down. The relative amount of the grey and white substance, and the differences in size and shape of the grey cornua in various regions of the cord, may be understood from the accompanying diagrams of sections at different parts.

The posterior cornua, coming to the surface, cut off from the rest of the white substance, that which lies between them, and this constitutes the posterior columns. Each posterior column thus lies between the posterior median septum and the posterior cornu. The posterior roots of the nerves do not all immediately enter the grey substance, but some of them course through the outer part of the posterior column, which we may term the postero-external column (P.E.C., Fig. 2). It has been termed by Charcot the "posterior root-zone." A septum of connective tissue (*s.*, Fig. 2) separates off, from this area, that part of the posterior column which is adjacent to the posterior median fissure, and the part so marked off is termed the "posterior median column." The distinction of these two portions of the posterior column is, as we shall see, very important in pathology. But it is to be noted that the fibres of the posterior roots only pass through the outer part of the postero-external column, and that these fibres in the lumbar region pass further into the column than the cervical region.

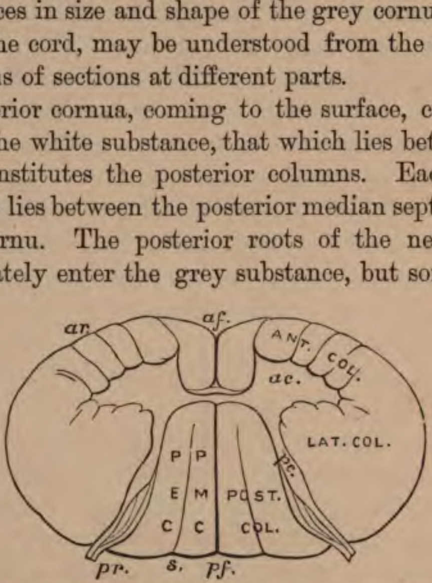

FIG. 2.—DIAGRAM OF SECTION OF SPINAL CORD IN THE CERVICAL REGION. The reference letters are explained in the text.

The portion of white matter which lies in front of and outside the grey, from the anterior median fissure to the posterior cornu, is structurally undivided, and is termed the antero-lateral column. It has been artificially divided into an anterior column, lying to the front and inner side of the anterior cornu, and a lateral column, lying outside the grey

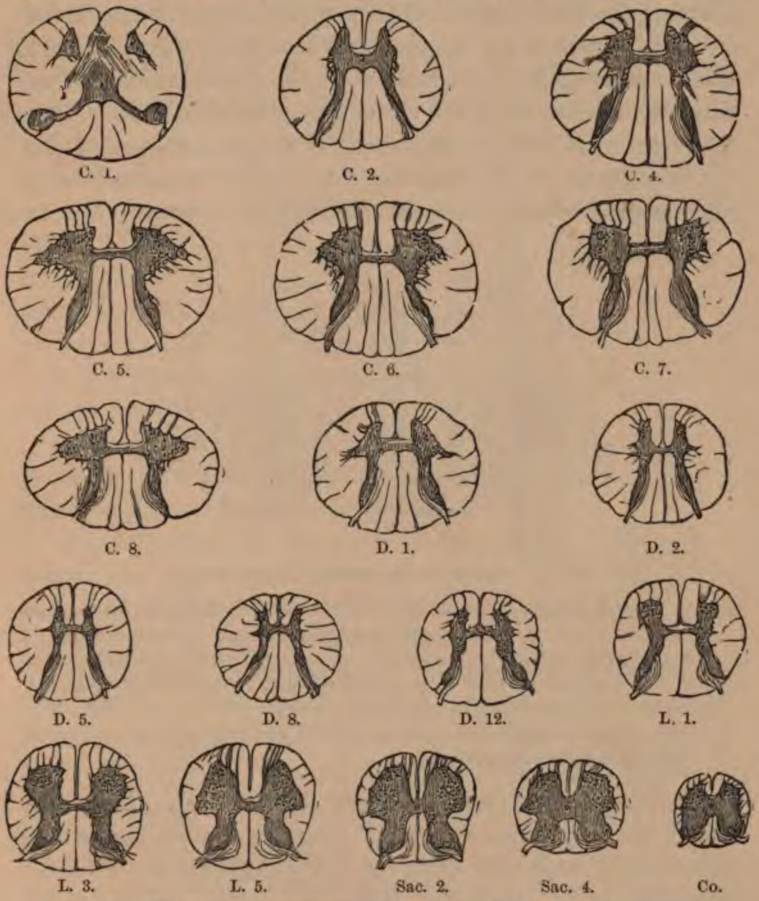

FIG. 3.—DIAGRAMS OF SECTIONS OF THE SPINAL CORD AT DIFFERENT LEVELS.

The letters and numbers indicate the spinal nerves to which the sections correspond. Each is figured twice the natural size. (From Quain's "Anatomy," 8th Edition.)

matter (Fig. 2). But pathology indicates a more important division than this, and the study of the development of the cord corroborates the teachings of pathology. If certain parts of the brain (concerned in voluntary motion) are destroyed, certain fibres degenerate throughout the cord, and this degeneration marks out for us the fibres which are in direct connection with the motor region of the brain. Two tracts are thus picked out, one in the posterior part of the lateral column, on the opposite side to the cerebral lesion; and one on the same side, in the anterior column, close to the median fissure (see Plate, Fig. 1, *a* and *b*). These are called the "pyramidal tracts," because the connection of these tracts with the brain is by means of the anterior pyramids of the medulla. They are shown on both sides, shaded transversely, in Fig. 4. Those adjacent to the anterior median fissure are the "anterior (or direct) pyramidal tracts"; those in the lateral column are the "lateral (or crossed) pyramidal tracts."

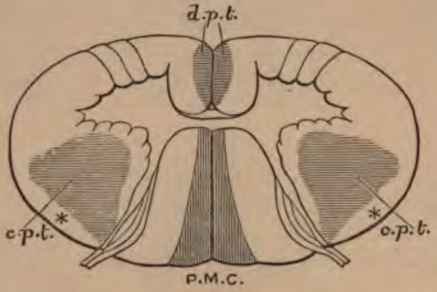

FIG. 4.—AREAS OF SECONDARY DEGENERATION.

P.M.C., postero-median columns, one on each side of the posterior median septum; *d.p.t.*, direct, or anterior, pyramidal tracts, one on each side of the anterior median fissure; *c.p.t.*, crossed, or lateral, pyramidal tract in the posterior part of each lateral column, and separated from the surface of the cord by (*), the direct cerebellar tract of Flechsig. The areas of ascending degeneration are shaded vertically: those of descending degeneration transversely.

The crossed (or lateral) pyramidal tract contains the motor fibres which have decussated in the medulla; the direct (or anterior) tract, those which have not decussated there. The relative size of these tracts varies in different individuals; the more fibres that have crossed in the medulla, the smaller is the direct tract, and *vice versâ*. The direct tract may even be absent, all the fibres having crossed above (Flechsig).

Regarding the lateral pyramidal tract, it may be observed that it is situated behind the level of the anterior cornu, that it does not usually extend quite up to the posterior cornu (although it may do so behind), and that it does not extend up to the surface of the cord, being limited by a zone (* Fig. 4), in which there is no descending degeneration. The fibres of this zone are said (by Flechsig) to descend from the cerebellum.*

We have further evidence that the fibres in the posterior parts of the lateral columns descend from above, in the fact that, if the cord is destroyed at any level, these fibres on each side degenerate below the lesion, just as they do on one side after a cerebral lesion. Such bilateral degeneration is shown in Fig. 5, C, *c c*, the lesion causing it being indicated at A. Bilateral degeneration of these tracts is shown also on the Plate, Fig. 2, *b b*. This degeneration is currently, although not very happily, termed "sclerosis," and the degeneration

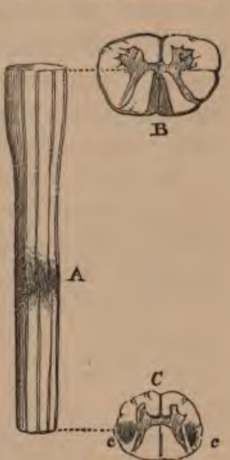

FIG. 5.

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* The direct pyramidal tract is also called the column of Türck; the postero-median column is called the column of Goll, and the postero-external column is called the column of Burdach. I have avoided the use of these terms. This system of nomenclature is full of inconvenience, increasing the difficulties of the student, and leading to frequent mistakes in scientific writings. There are very few observations in medicine regarding which it is not obvious that they would speedily have been made by some one other than the actual observer; that it was very much of an accident that they were made by certain individuals. Scientific nomenclature should be itself scientific, not founded upon accidents. However anxious we may be to honour individuals, we have no right to do so at the expense of the convenience of all future generations of learners.

of this area is designated "lateral sclerosis"—"descending lateral sclerosis," when it is the result of a lesion higher up.

I mentioned that the fibres of the white columns end at different levels, and so the white columns become progressively smaller. The portions of the white columns which constitute the pyramidal tracts follow the same rule, and hence the descending degeneration becomes smaller in area the lower we descend in the cord, and in the lowest part of the lumbar enlargement it is very small indeed. The fibres of the anterior pyramidal tracts disappear in the dorsal region, probably passing to the other side of the cord. Hence the descending degeneration from the brain, in the lower dorsal and lumbar region, is confined to the opposite lateral column. Hence, too, if the cord is compressed, the descending degeneration appears in the anterior pyramidal tracts only when the compression is high up.

A similar process of "secondary degeneration" furnishes corroboration of the distinctive division of the posterior column, which, as we have just seen, is suggested by anatomy. Below a point at which the cord is completely destroyed, although the lateral columns degenerate, the posterior columns present no change. Above the point destroyed, however (as at B, Fig. 5), while the lateral columns, and the postero-external columns present no change, in the postero-median columns the nerve-fibres disappear and become replaced by connective tissue.* This ascending degeneration is also shown in the Plate, Fig. 3, *c*. These are the only secondary degenerations commonly described. But I have found, in a spinal cord of which the lower extremity was crushed, a symmetrical area of slight ascending degeneration in the anterior part of the lateral columns, in front of the pyramidal tracts (Plate, Fig. 3, *e*). Of its possible significance I will speak presently.

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* This statement, although that which is current, is not strictly accurate. Some distance above the damage the ascending degeneration is confined to the postero-median columns; but close above the compression the degeneration extends outwards into the posterior portion of the postero-external column, not, however, to that part of it through which the posterior roots pass. Hence it is probable that the fibres which course upwards in the postero-median column enter it from the postero-external column.

The grey substance is composed of nerve-cells and interlacing fibres; some of the cells in the anterior cornua are very large and with many processes, and are called the "ganglionic" or "motor" nerve-cells. One process from each cell is undivided and constitutes the axis cylinder of a nerve fibre of an anterior roof. The other processes divide and subdivide in the substance of the grey matter.

II.—PHYSIOLOGY OF THE SPINAL CORD IN RELATION TO THE SYMPTOMS OF ITS DISEASES.

We may now consider the chief functions of the cord, and the effects of their impairment. In the spinal functions we have to distinguish two great systems of action—that by which the cord transmits, and that by which it controls; *i.e.*, its functions as a conducting organ, and as a nerve-centre, reflex and automatic.

Motor Conduction.—The conduction of motor impulses from the brain is in the antero-lateral white columns, probably in the pyramidal tracts; it is chiefly in the side of the cord corresponding to the limbs moved, the crossing taking place for the most part in the medulla. The motor path leaves the cord by the anterior nerve-roots, but does not enter them directly. The fibres of the pyramidal tracts enter the substance of the grey matter, and are apparently connected through this with the large nerve-cells from which the anterior root-fibres proceed. Hence both the matrix of grey matter and the motor nerve-cells form part of the motor path. The power of voluntary motion may be arrested by a lesion anywhere in this tract—lateral column of the cord, grey matter, and anterior nerve-roots. If the lesion is on one side of the cord, the loss of power will be on the same side, and in degree proportioned to the number of pyramidal fibres which have crossed in the medulla; and this, as we have seen, is not always the same.

Sensory Conduction.—All sensory impulses—of pain, touch, temperature—enter the cord by the posterior roots, passing, in part directly, in part through the postero-external columns, into the posterior cornu, and quickly crossing to the other side of the cord. There is some reason to believe that the paths of these several sensory impulses up the cord are not the same. That of pain has been commonly believed to pass up the central grey matter; that of touch, and perhaps also of temperature, passes up, in the opinion of some authorities, in the posterior column. But according to late, most careful, and apparently conclusive experiments by Woroschiloff (confirmed by Ott), such sensation as can be tested in the lower animals is conducted, in the dorsal region in the lateral columns. No facts have been hitherto recorded suggesting that this is true of man. But if sensation is conducted in part in the lateral columns, it is certainly not in that portion of them which is occupied by the pyramidal tracts, because there may be no loss when these are completely degenerated. It is probably, therefore, in front of these. This is the situation in which I have found the ascending degeneration in the case of crushed cord in which sensation was greatly impaired. (See p. 13, and Plate, Fig. 3, *e*.) This fact at present stands almost alone,* but, taken in conjunction with the experiments on animals, it points, I think, to the probability that some sensation is conducted in this region in man; what or whence, whether from the skin or deeper structures, we do not know.

We are still too ignorant of the paths of sensation for us to infer much from the form of its affection in spinal disease. One thing, however, seems clear—the path of sensation is less definite than that of motion. A very small portion of undestroyed cord will conduct sensation, but it is then, at least in its intenser form, commonly retarded. Each form of sensation may be impaired by disease of the posterior roots, either outside the cord or in the postero-external column through which they pass; or by disease of the conducting structures of the cord higher up; and, since the paths decussate in the cord, if the lesion is unilateral, sensation will be affected on the side of the body opposite to the lesion (motion being affected on the same side). A strong reason for believing that the paths are not the same is, that the senses of touch and pain and temperature are often impaired in different degrees. The most common change is for the sense of pain to be lost and touch preserved (analgesia). In such a condition the slightest touch of the finger may be felt readily, but a needle may be driven into the skin, and the patient experiences only the sensation of a touch. In other cases the sense of touch may be lost, and only the perception of painful impressions remain (anæsthesia). In other cases both are changed proportionately. To ascertain impairment, it is necessary to examine carefully the sensitiveness to each form of stimulation, to note how the patient feels the impression (since the sensation, when not lost, may be perverted), to note whether it is localized accurately, and to note whether it is unduly retarded. Sensations of pain and temperature are never so rapid as that of touch, and it is in these that the chief retardation takes place.

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* A confirmation of the occurrence of limited degeneration in this situation is furnished by an interesting observation by Dr. Haddon ("Path. Trans." vol. xxxiii. p. 21).

The functions of the ascending fibres of the postero-median columns are still unknown. Their degeneration does not seem to be accompanied by any impairment of sensation. We also know little of the function of those fibres of the antero-lateral column which lie in front of the anterior cornua.

Reflex Actions.—The next important function of the cord is its action as a reflex centre. We may regard the reflex system of the cord as made up of a series of nerve-loops or arcs, each posterior, sensory, root being connected with certain anterior, motor, roots by means of the grey matter (Fig. 6). This consists partly of the large motor nerve-cells, and partly of a network of the finest nerve-filaments and minute nerve-cells. The connection of the roots, through the grey matter, is apparently by this network of fine fibres, which interlace like the filaments of a sponge. But in this there are paths of different resistance, so that a slight stimulus may pass by the most ready path to a certain anterior root, while a stronger stimulus may diffuse itself more widely and affect many nerve-roots. For instance, a gentle touch on the sole may cause only a movement of the toes; a stronger touch, a start of the whole leg. A similar wide diffusion may occur in pathological states of the cord. These reflex loops are also connected with the conducting tracts to and from the brain.

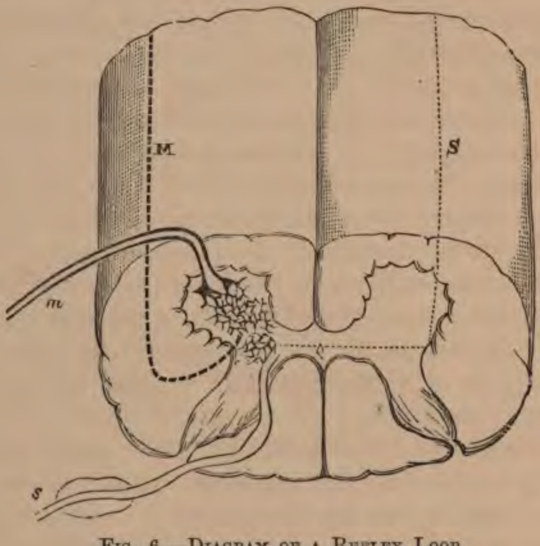

FIG. 6.—DIAGRAM OF A REFLEX LOOP.

M, conducting motor tract; *m*, anterior, motor, nerve-roots; S, conducting sensory tract; *s*, posterior, sensory, nerve-roots.

A motor impulse, passing down the cord in the white column (M), leaves the cord by the anterior roots (*m*), which are part of the reflex loop, and enters the anterior roots by the grey matter and motor nerve cells, which may be regarded as part of the reflex centre. So, too, the sensory impulse enters the cord by the posterior nerve-roots (*s*), which are also part of the reflex loop, and then, leaving this loop, ascends the opposite side of the cord to the brain. Thus the same peripheral impression excites a conscious sensation and a reflex action; and, on the other hand, we can, if we wish, execute voluntarily a movement of the leg quite the same as the reflex action. Moreover, we can exercise some voluntary control over the reflex movement, and prevent or lessen the start of the leg.

The value of the reflex actions in diagnosis is, that their persistence is proof that there is no considerable disease in the reflex loops by which they are produced. They thus yield us very important diagnostic information. Both their absence and their excessive degree are significant. It will be well, therefore, to study them in more detail.

It is necessary to distinguish two forms of reflex action. The first is that excited by stimulation of the skin, by a touch, scratch, prick, etc. On gentle stimulation, contraction occurs in the muscles at or near the spot. A series of such reflex actions can often be obtained in the normal spinal cord, from the lowest extremity of the cord to the lower part of the cervical enlargement. In some cases they are of considerable diagnostic importance. Beginning below, we have the well-known reflex from the sole (plantar reflex) which depends on the lower part of the lumbar enlargement, when the movement which results is confined to the foot-muscles. (See Table, p. 60.) Next, irritation of the skin of the buttock, in some individuals, excites a contraction of the glutei—the gluteal reflex, we may call it—depending, I believe, on the cord at the level of the 4th or 5th lumbar nerve. Next, there is the well-known cremaster reflex, by which the testicle is drawn up when the skin on the inner side of the thigh is stimulated. This arises at the level of the 1st and 2nd lumbar pairs. It may often be excited by stimulation of any part of the front and inner side of the thigh.* Next, there is the abdominal reflex—a contraction in the abdominal muscles, when the skin is stroked on the side of the abdomen, from the edge of the ribs downwards. This is produced in the cord from the 8th to the 12th dorsal nerves. Next, a stimulation on the side of the chest, in the 6th, 5th, and sometimes in the 4th intercostal spaces, causes a dimpling of the epigastrium on the side stimulated. I think that it depends on a contraction in the highest fibres of the rectus abdominis; it is singularly uniform in its occurrence. We may term it the epigastric reflex; it depends on the spinal cord from the 4th to the 6th or 7th pairs of dorsal nerves. There is no higher reflex on the front of the trunk. If we turn to the back, we shall find that in some patients, from the angle of the scapula to the iliac crest, stimulation of the skin along the edge of the erectors of the spine excites a local contraction in these muscles. These dorsal and lumbar reflexes, as they may be termed, are only of corroborative value, as they are less active than the more convenient abdominal and epigastric reflexes, which are produced in the same region of the cord. Irritation of the skin in the interscapular region gives us, however, the highest reflex available—a contraction in some of the scapular muscles, when slight, chiefly marked at the posterior axillary fold (teres); when more considerable, involving almost all the muscles attached to the scapula—trapezius, teres, serratus—and even moving the bone a little outwards. We may term it, therefore, the scapular reflex, and it is produced in the cord at the level of the upper two or three dorsal and lower two or three cervical nerves.

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* This reflex has been carefully studied by Jastrowitz, and by Weir Mitchell.

Thus in these reflexes—plantar, gluteal, cremasteric, abdominal, epigastric, and scapular—we have the means of ascertaining something of the condition of almost every inch of the spinal cord from the cervical enlargement downwards. The presence of the reflexes is proof that the reflex path through the cord is not seriously uninterrupted, but we cannot *simply* infer from their absence that this path is impaired. The reflex excitability of the cord varies much in different individuals, is always greatest in early life, and is often lessened in the old. Some of these reflexes are thus absent, apart from disease, especially the gluteal and lumbar reflexes, and sometimes the cremaster reflex; the abdominal reflex is also lessened by laxity or distension of the abdominal parietes. It is a remarkable fact, also, that disease of one cerebral hemisphere lessens or abolishes these superficial reflexes on the opposite (paralysed) side of the body. The diminution may be observed immediately after the occurrence of the cerebral lesion, and may be permanent. It is an effect very difficult to explain, because these reflexes are increased if the disease, which lessens voluntary power, is not situated in the brain, but is high up in the cord.* The effect of cerebral disease does not interfere materially with the use of these reflexes as indications of spinal disease, and it affords us an important additional indication of the existence of an organic disease of the brain. I will presently give you some instances of the utility of these reflexes in spinal diagnosis.

The second group of phenomena which depend on reflex action are those which have been termed "tendon-reflexes." These phenomena are of great practical importance, and it is necessary to describe their character and nature in some detail.†

We will first consider the well-known jerk of the leg which occurs when the patellar tendon is tapped. It has been called the "knee phenomenon" by Westphal, the "patellar-tendon reflex" by Erb. The latter designation has come into general use, although, as we shall presently see, it is an undesirable term. We may, therefore, speak of it either by the somewhat cumbersome designation proposed by Westphal, or by the simpler descriptive term "knee-jerk." It is not a little curious that this knee-jerk, which has for generations amused schoolboys, should have become an important clinical symptom.

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* There is, I think, only one possible explanation. In the frog the superficial reflexes are controlled by a centre, situated in the optic lobes, and are lessened, or at least retarded, if this is stimulated. It is probable, as just observed, that there is also in the higher animals a centre which has the power of controlling these reflex actions. If we assume that this controlling centre is itself under the influence of the highest motor centres—not an improbable assumption—all the phenomena are intelligible. The motor centres nominally restrain the controlling centre: if the motor centres (or path from them to the controlling centre) are damaged, this centre is unrestrained, and inhibits the superficial reflexes on the paralysed side. But disease in the cord interrupts, not only the voluntary path, but also that by which the controlling centre influences the superficial reflexes and so these are intensified in the paralysed parts.

† First systematically studied by Erb and Westphal, but previously partially recognized and employed in diagnosis by Charcot.

To obtain the jerk, the knee must be flexed so that the quadriceps femoris is gently extended, and the leg must be free to move. If then the patellar tendon is struck, the quadriceps contracts and jerks the leg forwards. The most convenient position is with the knee to be tested flexed nearly, but not quite, at a right angle. The posture commonly employed is with the leg to be tested across the other, the knee of the supporting leg being at a right angle (Fig. 7). But if the leg to be tested is stout, its tension in this position may be too great to permit of any movement. In such case the best posture is for the observer to place his arm beneath the patient's thigh, just above the knee, and rest his hand on the patient's other knee (Fig. 8). Not long ago I saw a rather stout man, well known to many members of our profession, who was uneasy because a physiological friend had been unable to produce this phenomenon upon him. His legs were so stout that, in the posture commonly employed, no movement occurred when the patellar tendon was struck. But when the thigh rested on the observer's arm, in the way I have described, the tap on the tendon caused a ready jerk, much to the satisfaction of the individual examined, whose anticipations of impending locomotor ataxy were thus removed. Children may sit on the edge of a chair, adults on the edge of a table; but if so, and the legs are vertical, the effect of the blow and of the muscular contraction must be carefully distinguished. The side of the extended hand is a convenient instrument for giving the blow (Fig. 7). Now and then, when very slight, a percussion hammer (Fig. 8), or a stethoscope with an india-rubber edge to the ear-piece,* elicits it more readily, especially when (as in children) the space between the patella and tibia is too small to permit of a suitable blow with the hand. It may commonly be obtained as readily through one or two garments as upon the skin. If its existence is doubtful, however, the skin should be bared. In many cases the movement may be obtained by a downward blow upon the patella, by a blow on the quadriceps tendon above the patella, or by a blow on the substance of the muscle, almost as readily and strongly as by a blow on the patellar tendon. In cases in which it is in great pathological excess, it may even be excited by a blow on the tibia.

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* Such stethoscopes were formerly in use for percussion of the chest, and can be obtained of most instrument makers.

When it is in excess, the same phenomenon may be conveniently brought out in a somewhat different way. As the patient lies in bed, the finger of one hand is placed across the quadriceps tendon just *above* the patella, and the patella pushed down, so as to make the quadriceps tense. The finger is then percussed in the direction in which the patella is being pushed, so as, suddenly, to increase the tension in the muscle. The blow is instantly followed by a contraction, jerking the patella and finger upwards. Very often this single contraction is immediately succeeded by a second, and this by a third, and so on—a series of quick

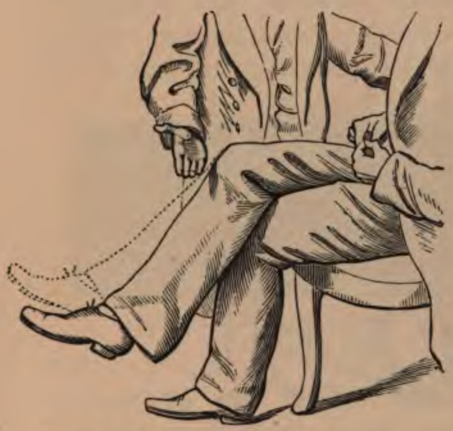

Fig. 7.—Ordinary mode of Obtaining the Knee-Reflex.

The dotted line indicates the movement which follows the blow on the patellar tendon.

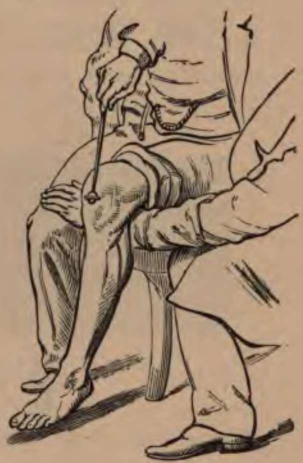

Fig. 8.—Knee-Reflex.

Method of obtaining it with a percussion hammer when it is not readily produced in the ordinary way.

clonic contractions, recurring as frequently as eight per second. By grasping the patella firmly, and suddenly pushing it downwards, so as to make the muscle tense, this clonus may also be set up, as Erb has shown. It may continue as long as tension is kept up, but instantly ceases when the muscle is relaxed.

The next important phenomenon belonging to this group occurs at the ankle-joint. If the calf-muscles, which are connected with the Achilles tendon, are made tense, and this tendon is tapped, the muscles contract, causing a slight extension movement of the foot; just as the muscles of the thigh contract, when the patellar tendon is struck. In cases in which these phenomena are excessive, —just as sudden tension in the thigh-muscles will cause a contraction, followed by others in a continuous series—so, in such cases, if the calf-muscles, which extend the ankle-joint, are suddenly put on the stretch by pressing the hand against the sole of the foot (Fig. 9), a quick contraction occurs, instantly ceasing, but, if the pressure is kept up, instantly renewed, and recurring, as long as the tension is maintained, as a clonic series of spasmodic contractions—the "ankle-clonus," or "foot-clonus" (or "foot

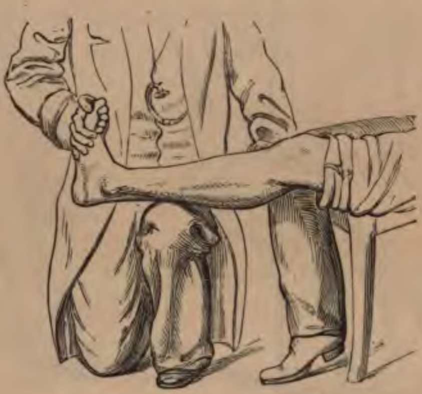

FIG. 9.—METHOD OF ELICITING THE FOOT-CLONUS BY PASSIVE FLEXION OF THE FOOT.

phenomenon"—Westphal). It can often be obtained best when the knee is not completely extended. The movement is very uniform, from six to ten contractions occurring per second. By attaching a writing point to the foot, and making it trace a line on a revolving cylinder covered with blackened paper, I have obtained such tracings as I now show you (Fig. 10), which are almost as regular as the tracings of a tuning-fork. This foot-clonus can be more frequently obtained than the clonus in the extensors of the knee, but the two have the same time, and are evidently of the same nature.

What is the nature of these phenomena? When a tendon is tapped, and its muscle contracts, the occurrence has somewhat the aspect of a reflex action. It was assumed by Erb that the contraction is a true reflex action, the stimulus being the excitation of nerves in the tendon. Hence it has been termed "tendon-reflex." This view has received apparent confirmation by the discovery of certain facts: (1) That there are nerves in tendon.* (2) That these phenomena depend for their occurrence on the integrity of the reflex path to, through, and from the spinal cord, and are arrested by a lesion in this path. By experiments on animals (in whom similar contractions may be obtained) it has been found that they are prevented by division of the nerves to the muscles, by division of either the anterior or posterior roots of the spinal nerves,

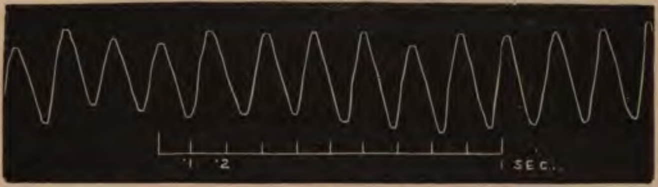

FIG. 10.—TRACING OF THE FOOT-CLONUS IN PARAPLEGIA.
(The tracing reads from right to left.)

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* It does not need the microscope to demonstrate this, as any one may ascertain who will take the trouble to give his Achilles tendon a sharp pinch.

were a reflex process, and rather more for the movement at the ankle. I have found that when the Achilles tendon, or the front of the leg is tapped, the resulting contraction occurs in about one-thirtieth of a second.* The interval for the knee-jerk has been found to be about one-twenty-fifth or one-thirtieth of a second.† If the patella is pressed down and tapped, in the way I have just described, I have found that the interval between the tap and the resulting contraction is often not more than one-fortieth of a second. The shortness of the interval makes it difficult to believe that these contractions can be reflex, and supports the theory that they are excited locally.

But to this view, that the contractions are excited locally, is apparently opposed the fact that they are prevented by whatever lesion arrests reflex action. Some have endeavoured to explain the discrepancy by the suggestion that reflex action may occur in a much shorter time than is commonly supposed. This suggestion is not at present justified by any known facts. Another and, I think, much more probable explanation is this. If we regard the contractions as local, we have still to account for the irritability which permits the local stimulus to cause a contraction. This irritability is developed by passive tension. If the muscle is relaxed the fibres may contract if they are struck directly, just as do the fibres of a separated frog's muscle, but no contraction can be produced by striking the tendon. Hence I have suggested that the tension excites, by a reflex influence, a state of extreme irritability to local stimulation,—such as that of a tap on the tendon, or such as the vibration from a tap near the muscle, or from a tap on the bone to which the tendon is attached,—which thus excites a visible contraction.*

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* "Med.-Chir. Trans." 1879, p. 292. The measurement has been since confirmed by Waller, "Brain," July, 1880.

† ·039 sec. Burckhardt; ·032—·034 sec. Tschirjew; ·04 sec. Brissaud; ·03—·04 sec. Waller; ·3 sec. Eulenberg. Some measurements which I made of the interval ("Med.-Chir. Trans." 1879, p. 275) gave a longer interval, probably in consequence of the movement of the foot being taken as the indication of the commencing contraction. "Load" will increase greatly the period of latent stimulation, probably by causing the initial contraction to expend itself on the elasticity of the muscle. The measurements given above were obtained by recording the commencing contraction of the muscle.

The explanation receives some confirmation from the very interesting observations of Tschirjew.† He has found that if the nerve to a separate muscle be divided, the muscle remains of just the same length. If, however, a weight be first attached to the muscle, when the nerve is divided the muscle lengthens. This shows that the tension does excite a slight contraction which is dependent on a central influence. It is in this condition only that the local stimulation is effective. If the tension put on a muscle is gentle and gradual, it may only develope the irritability, and an additional local stimulation is necessary to produce a visible contraction. If, however, the tension is sudden and forcible, it not only developes the irritability, but produces visible contraction in the muscle thus rendered irritable—as in setting up the foot-clonus. I have shown ‡ that the relaxation of the muscle, between the successive contractions, is not complete: there is a persistent residual contraction, *i.e.*, a tonic contraction on which the clonic contractions occur. When one clonic contraction is over, the tension continuing, a second is instantly developed.

The sensory nerves of muscles have been shown by Tschirjew to commence, not within the muscular fibrils, but in the interstitial connective tissue. The afferent impulse produced by tension is apparently due to the tension acting on these nerves: the visible contraction is excited by tension or vibration affecting the muscular fibres themselves. The latter is ineffective unless the muscles are brought into a state of special excitability through the cord. Of the reality of an afferent impulse from the muscle, produced by tension, you may easily convince yourselves, if you will allow your ankle to be suddenly flexed. A distinct pain is felt in the muscle (none, be it observed, in the tendon). It is not surprising, therefore, that this afferent impulse should, very often, not merely develope the reflex excitability, or tonic contraction, but also cause a more widely-spread reflex action. The attempt to get the foot-clonus, for instance, will cause a flexion of the hip-joint; the attempt to obtain the knee-jerk may cause a movement in the opposite leg or a start back of the body. But these reflex contractions, if carefully observed, confirm the theory which has been put forward in the preceding pages, for they distinctly succeed, at an appreciable interval, the local contraction. If, for instance, in a patient now under my care, I depress the patella so as to make tense the quadriceps, and then tap the depressing finger, the tap is followed, after an interval too short to be recognized, by a contraction in the muscle, and after a very distinct interval (which I have found to be about three times as long as the other), by a contraction in the opposite leg. So, too, Burckhardt has found that the latent interval for a skin-reflex is three times as great as for the knee-jerk. I think that this theory of reflex irritability and local stimulation affords a full explanation of all the relations of these phenomena to the central nervous system, and to the other phenomena of disease, and it is the only theory which adequately explains them.

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* This explanation was originally given for the "foot phenomenon" alone ("Med.-Chir. Trans." 1879, p. 295). I now think that it is equally applicable to the knee-jerk. The evidence of the identity in nature of the two is very forcibly stated by Waller (loc. cit.).

† "Reichert und Du Bois Reymond's Archiv." 1879. ‡ Loc. cit. p. 286.

It seems, therefore, most desirable to discard the term "tendon-reflex" altogether. The phenomena are, according to the explanation above given, dependent on a "muscle-reflex" irritability, which has nothing to do with the tendons. If we wish to describe them by a general term, it will be best to employ one which does not involve any special theory of their nature. They may be termed "tendon-muscular phenomena," but the intervention of tendons is not necessary for their production; the one condition which all have in common is that passive tension is essential for their occurrence, and they may more conveniently be termed *myotatic* contractions (*τατικος*, extended).* The irritability, on which they depend, is due to and demonstrative of a muscle-reflex action which depends on the spinal cord.

A true "tendon-reflex" may be excited by pinching the tendon, but this is a start of the whole limb, precisely such as results from a pinch of the skin.

A clonus quite similar to that just described can be sometimes obtained in the peronei (a lateral foot-clonus), and also in the plantar muscles of the great toe—in each case by passive tension. All have nearly the same time—about eight per second.

It is of interest to note that modern physiologists know nothing of muscular "tone" except as developed by tension, and it is highly probable that the condition on which the myotatic irritability depends, is identical with muscular "tone." It is not, therefore, surprising that we are able, even in health, to get evidence of a tendency to rhythmical contraction. If a rhythmical contraction can be set up voluntarily, and gentle tension in the gastrocnemius maintained, as by sitting on the edge of a chair with the ball of the foot resting on the ground, the contractions will go on involuntarily—a normal foot-clonus, which has precisely the same time (about six per second) as the morbid clonus (Fig. 12). A prolonged voluntary contraction

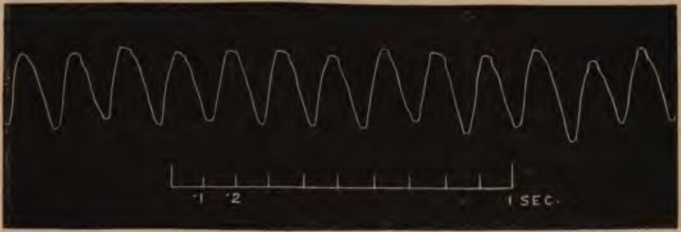

FIG. 12.—NORMAL FOOT-CLONUS.
(The tracing reads from right to left.)

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* If it should ultimately be proved (which is very improbable) that so short an interval as one-fortieth of a second is sufficient for a reflex action, and that each contraction is reflex, the term "myotatic" will still be accurate, since it will remain true that tension is essential for the production of these contractions.

of the calf-muscles against a considerable resistance (as in standing for some time on tip-toe) is also broken into clonus. These are evidently the same phenomenon, the difference being that it cannot in health be excited by passive tension. For *this* to be effective a morbid reflex irritability is needful, such as only exists in disease. In morbid states, in which the myotatic irritability is excessive, the posture I have just described excites the clonus very readily; and the jerking legs of paraplegics as they sit must be familiar to you. In attempting to walk, also, the tension on the calf-muscles has the same effect, and the patient may be jerked violently by the spasm.

It is probable that this reflex relation between tension and contractility of muscles is of the highest importance in their associated action, and that the reason why, in certain muscles, as those of the calf, these phenomena are more readily observed, is because in these, during the process of walking, at every step contraction succeeds tension, and so the reflex relation between the two has attained a higher degree of development. It is rare to get a distinct clonus in a child who has never walked, even in the pathological conditions in which in adults it would certainly be obtained.

The excess of these myotatic contractions is especially related to degeneration in the lateral column of the cord (pyramidal tracts). It is seen in extreme degree, for instance, in lesions of the cord higher up, which cause descending degeneration in those columns. It is seen also in cases of hemiplegia with similar descending degeneration on the paralysed side. The excess is apparently not due to the simple loss of a cerebral influence. It does not, as a rule, occur immediately, but developes gradually at the end of a week or ten days, *i.e.*, after a time sufficient to allow the nutrition-changes of commencing degeneration to pass down the lateral (pyramidal) fibres to the neighbourhood of the muscle-reflex centres. Over-action of these centres follows, and must be ascribed to the loss of some controlling influence. But the control cannot be exerted by the fibres themselves, or the over-action due directly to their degeneration, since the fibres only conduct, and do not originate nerve force. The pyramidal fibres enter the grey substance, and apparently end in its interlacing network of fine fibres and minute nerve cells, and by means of this structure are connected with the large ganglion cells of the motor nerves. The phenomena are best explained by the hypothesis that this structure, in the matrix of the grey matter, controls the muscle-reflex centres (of which the ganglion cells are part), and that the degeneration of the pyramidal fibres, which can be traced to the grey matter, invades this structure. The loss of its influence permits the over-action of the muscle-reflex centre. The foot-clonus can often be obtained in slight chloroform narcosis, but under the full action of chloroform it disappears; apparently this agent influences the controlling structure before it influences the muscle-reflex centres. Ether and nitrous oxide do not abolish myotatic irritability (Horsley). After an epileptic fit, again, a clonus can be obtained for a few minutes, while after a very severe fit, the myotatic irritability, instead of being increased, may for a few seconds be lost, so that not even the knee-jerk can be obtained. In the first case the discharge appears to temporarily exhaust the controlling structure; in the second, the more severe action exhausts also the muscle-reflex centre itself.*

It is uncertain whether we should ascribe all over-action of these centres to loss of control. We are justified in doing so when the over-action follows permanently a destroying lesion, such as the degeneration of the lateral columns. Slight over-action is sometimes present when there is no evidence of such a process, but in which there are indications of irritability of the spinal cord, as in cases of hysteria with spinal tenderness. It is possible that in these cases we have a primary over-action of irritable centres.

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* I do not know of any pathological observations of the state of the matrix of the grey substance when there is degeneration of the lateral columns without affection of the motor ganglion cells. The investigation is very difficult on account of the character of the structure. In cases so extremely rare as to be manifestly exceptional in mechanism, the foot-clonus has been observed a few hours after the onset of hemiplegia. It is probable that in these cases the controlling structure is inhibited by the irritation of the cerebral lesion. A case lately seen suggests that the knee-jerk may even be lost during the first hour after the onset, and then return: the irritative inhibition extending to the muscle-reflex centre itself.

The diagnostic importance of a considerable increase in myotatic irritability can hardly be over-estimated. By "considerable increase" I mean such a degree that a uniform clonus can be obtained by simple passive flexion of the foot. I believe that such a clonus is always pathological, always indicates grave nutritive changes in the spinal cord, and that there is, in most cases in which it can be obtained, actual degeneration in the fibres of the lateral columns.

A circumstance which gives to this sign a special diagnostic importance, is that in the cases in which it occurs the nutrition of the muscles and sensibility of the skin are often unimpaired, and the weakness in the legs is likely to be regarded as "functional," or, if in a woman, as "hysterical." In hysterical paraplegia the myotatic irritability is often perfectly normal. It is not uncommon, however, in these cases, to have, with spinal tenderness, an increased knee-jerk, but I have never seen, in any case of hysterical paraplegia, a foot-clonus such as is above described, and is so common in organic cases. But a spurious, or voluntary foot-clonus is occasionally met with in hysteria, which needs to be carefully distinguished from the typical form. In the latter, when the foot is first pressed up, the clonus at once commences and continues without variation as long as the pressure is maintained. But in the voluntary form there is no clonus during the first few seconds, then the foot and observer's hand are pressed down by a voluntary contraction in the calf-muscles which is broken by clonus. This clonus may continue, but varies in degree (together with the pressure downwards of the foot) from time to time. This variation and the dependence of the clonus on voluntary contraction of the calf-muscles, can be readily recognized.

Similar myotatic contractions may be obtained in the arm. A tap on the extensor tendon above the olecranon will cause a contraction in the triceps. When they are in excess a tap on the bone to which the tendon is attached will cause a contraction in the muscle. Thus a tap on the radius will cause a contraction in the biceps, slightly flexing the elbow; a tap on the ulna will produce contraction in the triceps, or in the forearm muscles connected with the bone, just as a tap on the tibia, in similar conditions, will cause the knee-jerk. A clonus may even sometimes be obtained in the biceps, or flexors of the fingers, by sudden tension, quite similar in time and character to the ankle-clonus. In many cases these contractions can be obtained without any other passive tension than is involved in the posture of the arm. In hemiplegia the increased muscular tension which is involved in the condition of rigidity seems to suffice for permitting their occurrence. Each contraction is excited by the mechanical stimulation of the jar or of the increase of tension produced by the tap.

The myotatic irritability is lost in diseases which separate the muscle from the spinal cord (as a lesion of the nerve), in disease of the posterior roots (such as exists in posterior sclerosis), in disease of the anterior roots (as in chronic meningitis compressing the nerve-roots), and in disease of the grey matter at the level from which the nerves for the muscle proceed (as in infantile paralysis and allied diseases). It is also lost in diphtheritic paralysis * (in which there is an affection of the motor nerves and their cells) and in pseudo-hypertrophic paralysis (probably by reason of the disease in the interstitial tissue of the muscle in which the afferent nerves begin).

In employing these contractions for purposes of diagnosis, it must be remembered that they are, in health, similar on the two sides. A difference between the two sides is always pathological. For instance, the front-tap contraction can sometimes be obtained in persons in whom there is no reason to suspect organic disease. But the

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* Erb, Buzzard. I have several times observed the same fact.

presence of the front-tap contraction on one side, and its absence on the other, shows, without doubt, some structural change. Not long ago I saw a young married lady suffering from weakness of the legs. She was very anæmic, and the paraplegia had been regarded as unquestionably "hysterical," and she had been urged to exert herself and shake it off. The only absolute objective sign was that the front-tap contraction was very well marked on one side, and entirely absent on the other. This was strong evidence of structural change in the cord. This diagnosis was confirmed, only too sadly, by the subsequent progress of the case, for I afterwards heard that the patient became completely paraplegic, bed sores formed, and it seemed likely that she would die.

Before leaving these spinal reflex phenomena, I may, parenthetically, illustrate, by an example, the manner in which they are changed in cerebral disease, and the occasional diagnostic importance of their alteration. The cutaneous reflexes, especially the trunk reflexes, are often lessened, but the myotatic contractions are increased when there is any degree of descending degeneration in the cord. Under these circumstances the foot-clonus and front-tap contraction may be obtained. Not long ago, in investigating these reflexes, I examined a man who was thought to be suffering from idiopathic epilepsy. No weakness was complained of. The epigastric and cremasteric reflexes were, however, absent on the right side, and the abdominal reflex was slight, although all were well marked on the left. In the right leg the knee-jerk was excessive, and the foot-clonus and front-tap contraction could readily be obtained, while they could not on the left. This alteration affords the strongest grounds for suspecting organic brain disease, and its discovery led to careful examination of the strength of the right limbs. Slight but distinct weakness of the right arm and leg was found, and subsequently increased, and optic neuritis developed. In this case organic disease of the brain might readily have been overlooked, and probably would have been overlooked for a time, had it not been for the indications afforded by these phenomena.*

Co-ordination of Movement.—The next function of the spinal cord to be mentioned is that by which it influences the co-ordination of muscular movements. This function apparently depends upon the posterior columns, for it is lost when there is disease in this situation, as in locomotor ataxy. It is not, however, the whole of the posterior columns which are related to the function, but merely the part distinguished as the postero-external column or root-zone, that through which the fibres of the posterior roots pass. The most distinct ataxy may result from disease limited to this situation (Plate, Fig. 5).

Why does disease of the posterior columns interfere with co-ordination? We have seen that, by means of the muscular reflex actions, muscular contractions become associated; tension influences contractility; and thus there is a reflex grouping of muscular actions, which undoubtedly plays a very important part, not only in the actual arrangement of the contractions, but also by, so to speak, moulding the spinal centres by establishing lines of lessened resistance through them, and so facilitating the voluntary co-ordination.† There is, I believe, another mechanism by which the impairment of reflex action may impair co-ordination. For any movement there must be not only a contraction of certain muscles, but also a proportioned relaxation of their opponents. There is reason to think that the relaxation is really due to a reflex action,* and this is also suggested by the fact, long ago pointed out by Duchenne, that the late rigidity of hemiplegia may commonly be readily relaxed by faradization of the opponents of the rigid muscles. If this is so, we obtain a glimpse of a very complex series of reflex actions, by which a relation is established between tension, contraction in the same muscles, and relaxation in their opponents, which must undoubtedly play a very important part in muscular co-ordination. These muscle-reflex processes in locomotor ataxy are almost always impaired (if we are to judge by the knee-jerk, which is commonly and early lost). Their loss is probably one factor in the inco-ordination of ataxy. It is possible also that, as Todd long ago taught, these postero-external columns contain fibres which connect groups of nerve-cells at different levels, and that upon this connection depends in part the association of muscular contractions, which is essential for co-ordinated movement. The impairment of this association, by posterior sclerosis, may be another element in the ataxy.

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* In this patient the right hemiplegia and the optic neuritis increased, and ultimately left hemiplegia gradually supervened. After death there were found tumours in each hemisphere of the brain. That on the left side, which was the larger, the size of a pullet's egg, was situated above the lateral ventricle, beneath the upper extremity of the ascending frontal convolution, and it had extended through the lateral ventricle to the surface of the optic thalamus. It had clearly interrupted the connection of the upper "motor convolutions" with the motor tract.

† The springing movements observed by Woroschiloff in the hind legs of the rabbit after section of the dorsal cord, and regarded by him as "co-ordinated" in the lumbar enlargement, were probably merely a consecutive series of muscle-reflex actions, analogous to the slow knee-clonus which I have described ("Med.-Chir. Trans." 1879, p. 289).

But there are cases in which ataxy exists without loss of the knee-jerk, and with the foot-clonus. In these cases there is always loss of power as well as inco-ordination, and there is sclerosis of the lateral columns as well as of the posterior. The lateral sclerosis will tend to increase the muscle-reflex action, and, apparently, the damage to the posterior roots is then insufficient to arrest it, or the sclerosis is so situated as not to affect the posterior roots, although it may perhaps interfere with the connection between different groups of nerve-cells. It may be remarked that the inco-ordination is in these cases never quite like that in typical ataxy—there is more unsteadiness than inco-ordination. In other symptoms also these cases differ from those of pure ataxy. "Lightning pains" are rare and sensation is usually normal.

When superficial sensation is lost from the extensive damage to the posterior roots, this loss will greatly increase the ataxy by the removal of an important indication for cerebral guidance of movement. But since ataxy may exist without loss of superficial sensation, this is evidently not the *chief* element in the condition.

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* See "The Movements of the Eyelids."—"Med.-Chir. Trans." 1879.

In the inco-ordination of movement which depends on the spinal cord, we greatly intensify the manifestation of the trouble by reducing the base of support, since the smaller this is, the more accurate is the adjustment of muscular actions that is needed to maintain perfect equilibrium. Hence the ataxic has a difficulty in standing with his toes and heels close together; and if his feet are uncovered, the irregular muscular contractions are shown by the twitching of the tendons. Moreover, we increase his difficulty by making him close his eyes,—withdrawing, thus, the visual guidance. It has been said that this test is only effective when sensation is impaired in the legs, *i.e.*, when the sensory impressions from the legs are insufficient for cerebral guidance. This is, however, not true. The effect may be very marked when sensation is perfect. The maintenance of equilibrium is partly a muscle-reflex act, and if this function is slightly impaired, we can easily understand that it should be inadequate, unless supplemented by the visual information. Even when there is no inco-ordination, under perfectly normal conditions, closure of the eyes causes slight unsteadiness. In ataxy this is, so to speak, multiplied by whatever defect may exist.

It is important to be aware that the inco-ordination may not be equally distributed through the legs. In some patients it is marked in the muscles of the hips and knees, and the legs are raised too high, and brought down too suddenly. In other cases this characteristic is wanting; the inco-ordination affects chiefly the muscles of the feet, and causes unsteadiness of gait and irregular action of the foot-muscles in standing, or in movement of the feet, very conspicuous when they are uncovered.

Ataxy may be manifested, not only in the muscular contractions which produce movement, but also in those which should keep the limbs in a fixed position. It may be conspicuous, as already stated, in the attempt to stand upright. If the arms are affected it may be seen when the patient holds his hands out and tries to keep them in the same posture. Slow involuntary movements of the hands and fingers take place. These are increased in degree by closure of the eyes, and may resemble the movements of athetasis. The patient is unaware of their occurrence.

Controlling Functions.—We may consider next the controlling functions of the cord; and first, the influence which it exerts over nutrition. The nutrition of the limbs, etc., is, to a considerable extent, under the influence of the cord; that of the muscles, and probably also of the bones and joints, through the anterior nerve-roots; that of the skin probably through the posterior.

Muscular Nutrition.—For diagnostic purposes the most important is the influence on the nutrition of the muscles. The path of the influence is the motor-fibres in the anterior roots and nerve-trunks. Changes in the nutrition of the muscles, which are not due to local influence, depend on changes in the nutrition of the motor nerve-fibres. But the motor fibres are the prolonged processes of the motor nerve-cells, and may be regarded as parts of the nerve-cells, sharing all changes in the nutrition of the cells. The nerve-fibres are excitable by electricity, and changes in their nutrition are accompanied by changes in their excitability. By the use of electricity we are thus able to ascertain their state of nutrition, and to learn what is the condition of the nerve-cells in the cord, provided there is no disease separating the part of the fibre tested from the influence of the cells. Hence the value of electricity in the diagnosis of diseases of the spinal cord.

In a normal state, if you apply either the faradaic or the voltaic current to a motor nerve, there occurs, as you doubtless know, a contraction in the muscles, continuous when the faradaic current is applied, but, if the voltaic current is used, occurring only when the current commences or ceases to pass—*i.e.*, when the circuit is "made or broken." In proportion as the nutrition of the nerve-fibres is impaired, their excitability is lowered; a stronger current of each kind is required to excite them and cause contraction in the muscles they supply. When their nutrition is much impaired—*i.e.*, when the fibres are "degenerated"—no contraction can be obtained even with the strongest currents.

The changes in the excitability of the muscles are less simple, because in them there are two excitable structures—the terminations of the nerves, and the muscular fibres themselves. Of these the nerve-fibres are the more sensitive to faradization, and the faradaic stimulation of a muscle under normal circumstances is by means of these motor nerve-endings. Thus we find that its excitability corresponds in degree to that of the motor nerve supplying it. The muscular fibres themselves are, even in the normal state, less sensitive to faradization than the nerve, apparently because they are incapable of ready response to stimulus so very short in duration as are the shocks of which the faradaic current consists. (The proof of this consists in the fact that under the influence of curara, which removes the excitability of the terminations of the motor nerve, the muscle requires a stronger faradaic current to stimulate it than in the normal state.) But under these circumstances the slowly interrupted voltaic current stimulates the muscle as readily as in the normal state; a contraction occurs when the circuit is completed or broken—distinctly slower than that which occurs when the nerve-fibres are intact, and due to the stimulation of the protoplasm of the muscular fibres themselves. The fact that, under normal circumstances, the contraction which is caused by the voltaic current is as quick as that produced by the faradaic shock, is ground for believing that, in health, the voltaic, as well as the faradaic current, causes the muscle to contract chiefly by exciting the motor nerve-endings. When the motor nerve is degenerated, and will not respond to faradaic or voltaic stimulation, the muscle also loses all its power of response to the former. Apparently the nerve-degeneration is accompanied by changes in the nutrition of the muscular fibre, by which any power of response to faradization, which it possessed in the normal state, is lost. But the response to the voltaic current remains, and becomes quickly more ready than in health, doubtless in consequence of nutritive changes which develope what the older pathologists called, truly enough, "irritable weakness." Moreover, there may commonly be observed a change in the readiness of response to a certain mode of stimulation with voltaism—a "qualitative" change, as it is termed. In health, the first contraction to occur, on gradually increasing the strength of the current, is at the negative pole when the circuit is closed, and a stronger current is required before closure-contraction occurs at the positive pole. But, in the morbid state we are discussing, closure-contraction may occur at the positive pole as readily as at the negative, or even more readily—and contractions, when the circuit is broken, occur far more readily than in the normal state. This condition, then—faradaic irritability lost, voltaic irritability increased and often changed in quality—is termed the "degenerative reaction," because it occurs when the nerve-fibres are degenerated; and if we test *them* we shall find no response to any stimulus, voltaic or faradaic. It occurs when the nerves are separated from their motor nerve-cells, and if no such separation exists it indicates an acute degenerative change in those nerve-cells. It is well seen in acute myelitis of the anterior cornua (as infantile palsy).

But the motor nerve-cells and fibres often undergo changes in nutrition of a much more chronic character. In this condition the irritability of the fibres is lessened gradually and slowly. The irritability of the intramuscular nerve-endings is lessened in the same degree as that of the nerve-trunks, and we have a diminution to both faradization and voltaism. The nutrition of the muscular fibres is slowly, gradually, impaired; and when the nerve-fibres are much affected the muscular fibres are also. There is no stage in which the nerve-fibre irritability is lost, and the muscle-fibre irritability retained; hence there is no condition of lost faradaic and increased voltaic irritability such as characterizes the degenerative reaction just described. Irritability is changed to the one form of stimulus just as to the other. This condition is seen in many cases of progressive muscular atrophy, and also, in slighter degree, when the nerve-cells suffer, not in consequence of disease primary in them, but as a result of degeneration or irritation spreading to them from above. It is seen, for instance, in the wasting which occurs sometimes in hemiplegic limbs.

Between these two forms there are intermediate conditions, especially in cases of subacute disease of anterior cornua. For instance, the nerves may present normal irritability, and the muscle the increased voltaic irritability and changed order of contractions met with in degeneration. Probably, in these cases, some nerve-fibres are degenerated, and lead to the increased irritability of some muscular fibres. In both nerve and muscle the character of the reaction is determined by the more irritable structures; hence it is normal in the nerve and altered in the muscle. This is termed the "middle form" of degenerative reaction. It would be more accurate to call it the "mixed form."

The various changes in irritability have been thought to indicate the existence and various affections of separate centres for the nutrition of the nerves and muscles, apart from, though acting through, the motor nerve-cells. Remembering that the nerves and muscles contain fibres which suffer in different degrees, the phenomena at present ascertained may all be explained on the simpler principle stated, without the assumption of these special centres of the existence of which there is, indeed, no evidence.

Frequently the lowered irritability of degeneration in the nerves is preceded by a slight increase of irritability, very transient when the degeneration is acute, of longer duration when the degeneration is of the slower variety just noticed. Thus, in the early wasting of hemiplegia, increased irritability may be found, slowly giving place to diminution. In some morbid states, again, in which the change of nutrition in the cells and fibres is extremely slight, an increase may alone be discovered. I have found such an increase, for instance, in diseases regarded as functional, as paralysis agitans and chorea, and it is an interesting proof of the molecular changes which underlie, or result from, functional maladies.

In employing electricity as a means of diagnosis, at least one of the electrodes should be small, so as to be able to concentrate the current on a single muscle. Great care must be taken to place these electrodes on corresponding points on the two sides. It is convenient to be able to interrupt the current at the battery, so that the effect of the passage of the current may not be obscured by the mechanical effect of the application of the electrode.* In Stöhrer's faradaic battery the current can readily be stopped by pressing the hammer with the third finger, while the rod graduating the current is raised or lowered with the thumb and first finger. By moving the hammer slowly with the finger, we may employ the isolated faradaic shock. (The current consists of a rapid succession of shocks.) The isolated shock is often useful, because it is much less painful than the rapid series of shocks, and is especially convenient in the examination of children. A mechanical interrupter is essential in the case of the voltaic battery, in which the stimulation only occurs when the circuit is made and broken; and no battery is suited for use for diagnostic purposes which does not possess such a means of interruption. A galvanometer, to indicate the actual strength of current passing, is also very useful, since the number of cells employed affords little indication of the current which actually passes through the resistance of the skin, which varies much in different parts.

In examining muscles and nerves we avail ourselves, whenever we can, of the opposite side for comparison, and when we cannot, we must, if there is any doubt, compare the results obtained with those yielded by a healthy individual. Two conditions may be tested—first, the lowest strength of stimulus to which the muscle or nerve will respond; and secondly, the relative degree of response to a stronger current. The former is the more important, but has been insisted on too exclusively, for the latter is important also. If a few fibres of a nerve are healthy, and the others are degenerated, contraction may occur with as weak a stimulus as in the healthy nerve; but if the current be made a little stronger, the contraction in the diseased part may remain the same when that on the healthy side is energetic. Both irritability and power, therefore, should be noted, and also the order of reaction to voltaism.

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* The interrupting rheophores (containing a mechanism in the handle for making and breaking contact) are less convenient than they appear. In watching for the first flicker of contraction, it is essential that the rheophore should be held perfectly still, and the contact cannot be made or broken in the handle without causing a slight movement of the rheophore, which interferes with the detection of the muscular contraction.

The nutrition of bones and joints also probably depends on the anterior grey matter, but the influence is shown chiefly by the effect of disease in retarding the growth of bones. Now and then in posterior sclerosis (locomotor ataxy), a painless joint affection and brittleness of bones develope. When the upper dorsal cord is affected grave thoracic trouble may occur in a similar insidious way. Dyspnœa may lead to an examination of the chest of a patient who makes no complaint, and one pleural cavity may be found full of fluid.

The nutrition of the skin and subcutaneous tissues depends upon nerves which have their course in the posterior, sensory, roots, but whether there are special trophic fibres is unknown, and the centre on which the influence depends is also unknown. It is doubtful whether simple loss of the function of the posterior roots leads directly to lesions of nutrition. These may result indirectly in this condition; the anæsthesia deprives the patient of sensory information when change of posture is required to prevent damage from pressure. Occasionally, however, sloughing and vesication of the skin occur with extreme readiness, on the least local disturbance, and even with none. This is the case when the lesion is irritative in character, especially in destruction of the cord at the level from which the sensory nerves to the part proceed, and sometimes in disease higher up, as in some cases of acute myelitis.

Micturition and Defæcation.—The spinal cord possesses centres, situated in the lumbar enlargement, which preside over the action of the bladder and rectum. They are probably complex reflex centres: that for the sphincter ani is the more simple, but the system of action of each may be the same. In the wall of each viscus we have muscular fibres to expel the contents, and at the mouth a sphincter-arrangement to prevent their continuous evacuation. Fæces or air in the rectum, or urine in the bladder, excites the lumbar centre, and causes two effects—contraction in the wall and relaxation of the sphincter. This process may be, to a considerable extent, controlled by the will, although we are still ignorant of the precise mode in which the voluntary influence is exerted. But if the volitional path in the cord is interrupted above the lumbar centres, the will can no longer control the reflex processes; as soon as fæces irritate the rectum, they are expelled by the reflex mechanism; as soon as a sufficient quantity of urine accumulates in the bladder, a reflex contraction of the detrusor, and relaxation of the sphincter, cause its escape. The affection of the voluntary path for the sphincters is not always proportioned to that for the legs. If the damage to the cord involves also the sensory tract, the patient is unconscious of the action of the bladder or bowel. If the sensory tract is unaffected, the patient is aware of the process, but cannot control it. It is often said that there is permanent relaxation of the sphincters, but this is true only when the lumbar centres are inactive or destroyed. In this condition, evacuation occurs as soon as fæces or urine enter the bowel or rectum. The urine escapes continuously, instead of being expelled at intervals. The condition is less obvious in the case of the rectum, because there is not such continuous entrance of fæces into the rectum as there is of urine into the bladder. We may, however, distinguish between the two states of the rectum by the introduction of the finger. If the lumbar centre is inactive, there is a momentary contraction, due to local stimulation of the sphincter, and then permanent relaxation. If, however, the reflex centre and motor nerves from it are intact, the introduction of the finger is followed, first by relaxation, and then by gentle, firm, tonic contraction. I have verified this by introducing an india-rubber cylinder instead of the finger, and registering the pressure on the cylinder by connecting it with a recording apparatus, and have found that the relaxation is preceded by a very slight, brief contraction, and is followed by unbroken tonic contraction. The relaxation may also be readily produced by any impression on the mucous membrane of the rectum above the sphincter.

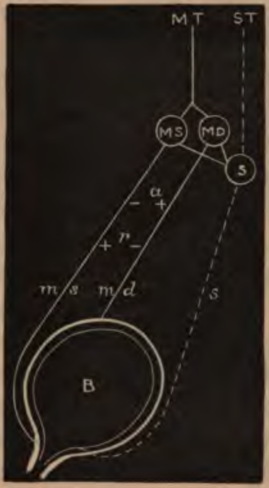

FIG. 13.—DIAGRAM SHOWING PROBABLE PLAN OF THE CENTRE FOR MICTURITION.

MT motor tract, ST sensory tract in the spinal cord; MS centre, and *ms* motor nerve for sphincter; MD centre, and *md* motor nerve for detrusor; *s*, afferent nerve from mucous membrane to S, sensory portion of centre; B, bladder. At *r*, the condition during rest is indicated; the sphincter centre being in action, the detrusor centre not acting. At *a*, the condition during action is indicated; the sphincter centre being inhibited, the detrusor centre acting.

In cases of gradual disease we may often trace the gradual loss of voluntary power over the process of micturition. In some cases this loss of power appears to be manifested as an inability, not to restrain, but to excite the action of the centre, and we have then a tendency to retention. Many conditions can be best understood by assuming that the motor centre really consists of two parts —one (MS, Fig. 13) maintaining the contraction of the sphincter, the other (MD) exciting the contraction of the detrusor fibres, and that these two parts are antagonistic: when one acts the other is inhibited. Thus, in normal rest, the sphincter centre is active, the detrusor at rest. Action is produced by a conjoint afferent impulse from the bladder and voluntary impulse from the brain. Then the detrusor centre acts, and the sphincter centre ceases to act. If voluntary power is impaired, the afferent impulse from the bladder may be insufficient, and then there is retention, or in other such cases the motor centre may yield too readily to the afferent impulse, and there is reflex incontinence.

Sexual Functions.—The conditions of the sexual organs depend on the integrity of the reflex loop to and from a special centre, also situated in the lumbar enlargement, but the due action of this centre depends on cerebral (psychical) as well as reflex influences. Disease of the centre, or of the nerves leading to or from it, abolishes sexual action. The sexual reflex is, however, one of the cutaneous reflexes, and it shares the condition of these rather than of the muscle-reflex actions.*

The centre is probably double, and its action is impaired by interference with either half. When, by disease higher up, the connection with the psychical centres is interrupted, the sexual act cannot be perfectly performed. If the path from the controlling centre (p. 19) is unimpaired, the reflex sexual processes are not in excess, may even be diminished; but if the path from this controlling centre is also interrupted, the reflex sexual processes are in excess like the other superficial reflexes, and priapism results. If the reflex centre is partially diseased, the sexual act is imperfectly performed.

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* This is sometimes well seen in locomotor ataxy. In rare cases of that disease there is satyriasis, and in such cases I have found a condition of extreme irritability of the cutaneous reflex actions.

The sexual centre is probably near that for the cremaster reflex, and from the latter we may, in some cases, gain information respecting the probable condition of the sexual centre, and in conjunction with the conditions just mentioned, of the sexual power. For instance, in locomotor ataxy, the cremaster reflex is rarely lost* without sexual power being lost or lessened also. Sexual power, may, however, be lost before the cremaster reflex, perhaps because more readily impaired. Again, in a patient with extensive disease of the lower and middle part of the lumbar enlargement, greatest on the left side, in whom the cremaster reflex was present on the right side and lost on the left, sexual power was partially but not wholly lost.

Vaso-motor Centres.—The centres in the cord which influence the sympathetic and vaso-motor system of nerves are frequently affected in disease, and altered temperature, vascularity, and perspiration of limb result. In disease of the upper part of the cervical enlargement, especially in sudden lesions, hyperpyrexia may occur. But these symptoms at present are of little diagnostic importance, except when the disease is in the cervical region, and the vaso-motor change is conspicuous in the face. Then, if one side is affected, unilateral sweating and flushing are conspicuous, and are due to the fact that sympathetic fibres for the head arise in, or pass through, the cervical cord. In the same cases, the movements of the iris are impaired: irritation of the cervical origin of the sympathetic causing spasm of the radiating fibres (dilatation), paralysis of the sympathetic causing their relaxation (contraction of the pupil). In many degenerative diseases of the cord the reflex action of the pupil to light is lost, the pupils being usually, but not always, small, but (as Argyll Robertson first showed) the pupils almost always contract if an effort of accommodation is made. The reflex action is lost, but the associated action remains. When the pupils are small in these cases, they do not dilate on cutaneous stimulation, as they do in health (Erb). It is probable that these phenomena do not depend directly on the disease of the cord, but are due to an associated degeneration in the centres for the movements of the iris in the upper part of the pons.

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* It must be remembered that the cremaster reflex is sometimes absent, in adults, apart from disease. The statement in the text applies to the cases in which there was such a general absence of the superficial reflexes as suggested a pathological loss.

In this survey of the more important functions of the cord, and their derangement, we have passed in review the chief symptoms which guide us in diagnosis. One or two others, however, remain.

Pain, referred to the spine, occasionally present in organic disease of the cord, is more frequent in disease originating in the meninges or bones. But the frequency with which spinal pain is present in abdominal, especially gastric, disease, and in neuralgic affections, lessens its diagnostic value when it exists alone. It is probably no exaggeration to say that of one hundred patients who complain of spinal pain, in ninety-nine there is no spinal disease. Moreover, in cases of organic disease, pain is far less frequent when the disease begins in the cord, than when it commences in the protecting structures. In meningitis, acute or chronic, spinal pain is frequent, and in organic disease of the bones of the vertebral column it is an almost constant symptom, and is combined with local tenderness. The same combination of local pain and tenderness is seen, however, in some cases of neuralgic pain, "rachialgia." The distinction between the two is, that in organic disease there are indications either of displacement of the vertebræ or of changes in the cord.

A still more important group of pains are those which are referred to the parts to which the sensory nerves are distributed, and have hence been termed "excentric or irradiating pains." They are due to the irritation of the posterior nerve-roots in their passage through the intervertebral foramina, through the membranes, or through the posterior columns of the cord. Other similar pains are due, apparently, in some cases, to irritation of the sensory conducting tract higher up the cord.* They may be dull pains, singularly resembling rheumatism, and constantly mistaken for rheumatism by the patients themselves and their medical attendants. The mistake is the more easily made, because other symptoms suggestive of spinal disease may be inconspicuous, and the rheumatoid pains, in acute cases, may be accompanied by febrile symptoms, and in chronic cases may be influenced by weather, being much more troublesome in damp and cold than in fine and dry weather. In all cases, persistent rheumatic pains in the limbs should excite a suspicion of spinal disease, and watch should be kept for such symptoms as local loss of power, or alterations in reflex action. In other cases they are sharp darting pains, "like a flash of lightning and gone again," as they are often described by patients with locomotor ataxy, in which they are very frequent. Sometimes there is a momentary local stab, at others the pain seems to dart down the limb. The position in which these various excentric pains are felt—legs, trunk, or arms—depends (when the nerve-roots are irritated) upon the seat of the disease—in the lumbar, dorsal, or cervical region of the cord. Occasionally the irritation is felt, not as a sharp pain, but as a painful sense of tightness, as if a band were tied tightly around the limb or trunk—the "girdle-pain," as it is called. When there is transverse damage to the cord, at the lowest part of the healthy region there is a state of irritation of the sensory nerves, and this irritation (referred to the nerve-endings) causes the girdle-pain. When the nerve-roots are irritated by disease of the vertebræ, caries or cancer, the pain is very intense, and is especially increased by movement ("*paraplegia dolorosa*").

Whenever there are excentric pains there may be increased or diminished sensitiveness in the part to which the pains are referred. Spontaneous sensations are also common, the various feelings comprehended under the terms "numbness," "pins and needles," "furriness," "formication," and the like. The conditions in which they occur are various, but they should never be lightly passed over.

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* The latest physiological researches seem to show that the conducting tracts in the cord are not, as is commonly taught, entirely insensitive to local stimulation.

Spasm.—Muscular spasm is conspicuous in many cases of disease of the spinal cord. It depends on over-action of the motor centres. Primarily, perhaps, it is due to "diminished resistance" within them, but ultimately the functional action (and underlying nutrition) of these centres seems to be permanently altered. The motor centres are, as we have seen, both parts of the reflex centres, and the terminations of the path of voluntary impulse. Hence spinal spasm may be excited by peripheral impressions, or by attempts at voluntary motion. In some cases paroxysms appear to come on without excitation, especially during sleep. In sleep, however, the reflex action of the cord is very readily excited, and it is difficult to exclude slight reflex stimulation. As an acute symptom, spasm is almost confined to meningitis, and to some very rare forms of functional irritation. In meningitis the spasm is apparently reflex, produced by irritation of the nerves of the meninges. In chronic organic disease, spasm is usually a late symptom, of gradual development, and then its reflex character may often be distinctly traced. It occurs in cases in which muscle-reflex action is in excess, and this, as already explained, follows and indicates the occurrence of descending degeneration in the lateral columns (see p. 30). The increase in the muscle-reflex action is first manifested by an excess of the irritability which can be developed by tension (increased knee-jerk, foot-clonus), and this may be distinct at the end of a week or ten days. A further increase leads to occasional "stiffness" in the legs, especially at night; and ultimately there is developed a considerable degree of spasm, the condition known as "spasmodic or spastic paraplegia." Any peripheral impression, superficial or deep, pinching the skin, for instance, or sudden muscular tension, will then excite spasm. The attempt to elicit the foot-clonus may cause such muscular rigidity that no clonus can be obtained. In most cases the spasm is extensor in character, and evidently depends on the reflex mechanism which assists in maintaining extension of the legs in the erect posture. In health, when we stand, the muscles are in a state of balanced contraction, largely reflex, the afferent impulses being derived from muscles, possibly in part from joints. In spastic paraplegia a similar but more intense extensor contraction is excited by the same posture of the limb. Flexed, it may be supple, but extend it passively, and as soon as it is straight the muscles become rigid, and it cannot again be flexed except by considerable force. It is just as when a clasp-knife is opened, as soon as the blade is fully extended it becomes rigid. So this has been called "clasp-knife rigidity." Frequently the spasm fixes for the time both legs to the pelvis, and if one leg is lifted from the bed the other rises with it. The same extensor spasm occurs when the patient attempts to stand, and it often enables a patient to remain erect whose voluntary power would be insufficient for him to do so were he not aided by the spasm.

In some cases, especially during sleep, flexor spasm predominates, and the hip and knee joints become strongly flexed. On what the difference in the form of spasm depends we do not yet know. Spasm, especially flexor spasm, was formerly regarded as evidence of "chronic meningitis," because acute meningitis is accompanied by spasm. In many of these cases, however, there is no other evidence of meningeal disease.

Occasionally spasm occurs in violent paroxysms, first tonic, and then clonic, excited by slight peripheral impressions, and in some cases apparently spontaneous—the "spinal epilepsy" of Brown-Séquard. The resemblance to an epileptic paroxysm, however, is not close, and the quick clonic spasm depends on precisely the same conditions as the foot-clonus. The peripheral impression excites violent tonic spasm; as this is passing off, the tension on the imperfectly relaxed muscle is sufficient to develope clonic contractions, just as does the passive tension in the ordinary method of obtaining the foot-clonus, and so we have a series of quick clonic contractions succeeding tonic spasm. The effect is most conspicuous in the quadriceps extensor of the knee. Sometimes the initial tonic spasm is slight, and the spasm appears to consist entirely of clonic spasm.*

Thus these spasmodic phenomena indicate integrity of the reflex loops and functional over-activity of the reflex-centres. This over-action in chronic cases is the effect of disease above, in the lateral columns; the degeneration of their fibres extends down to the lower centres into the grey matter, and probably invades a structure in it which controls the muscle reflex action (see p. 30). The gradual development of the over-action indicates that it is the result, in most cases, of changes consequent on this degeneration. Control being thus removed, the excessive reflex action gradually leads to what may be termed, if the expression is permissible, a functional hypertrophy of the centres, causing persistent and extreme spasm.

Simple rigidity of muscles, varying too little to be termed spasm, occurs also in some forms of disease of the cord, especially in cases of muscular atrophy (degeneration of the anterior cornua), and is due to simultaneous (or, according to Charcot, preceding) degeneration in the lateral columns. Persistent shortening (contracture) occurs also in the antagonists of paralysed muscles, but now and then as a result of over-action from central disease. As a consequence of this the knees may become flexed or the heels drawn up. The latter form of rigidity, dependent on a primary over-action, is always associated with more or less general spasm in the limb—an important distinction from the condition in which such shortening is due to the paralysis of the opponents of the contracted muscles. Persistent contracture of the gastrocnemii, as part of "spastic paraplegia," is sometimes seen in adults, but is more common in children.

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* It is necessary to mention that the term "spinal epilepsy" has been misapplied in France to the foot-clonus.

III.—INDICATIONS OF POSITION OF DISEASE: ANATOMICAL DIAGNOSIS.

We may now consider, briefly, how the symptoms which we have studied are grouped in diseases of different regions of the cord. The various symptoms, and their significance, have already been considered in detail, so that it is necessary only to mention them here. Some lesions of the cord affect certain structures (white columns or grey matter) in a considerable vertical extent, the other structures being normal. Such affections have been called "system diseases." Others, again, are very limited in their vertical extent, and have been termed "focal" lesions. The latter may be limited to one structure, or may extend through a considerable transverse extent, even through the whole thickness of the cord—"total transverse lesions." The lesions which affect certain structures only, whether extensive system diseases or limited focal diseases, are called "partial lesions," and it is convenient to commence with these.

1. *Antero-lateral White Columns.*—Disease of the antero-lateral white columns causes loss or impairment of voluntary power below the lesion, descending degeneration in the pyramidal tracts, and over-action of the lower centres, especially of those concerned in the muscle-reflex processes. This over-action may be manifested only as excess of the myotatic contractions, or it may increase to spasm and rigidity—spastic or spasmodic paraplegia. There is no wasting unless the degeneration, extending from the lateral columns, invades the motor nerve-cells in the anterior cornua. Then we have a combination of spasm and wasting in which, if the cornual degeneration proceeds, the spasm and rigidity may lessen as the nerve-cells suffer. In disease limited to these columns (at any rate, when the disease is limited to the pyramidal tracts) there is no loss of sensation, or inco-ordination. These symptoms of "spasmodic paraplegia" may arise from a primary degeneration in the lateral columns, limited thereto; but such cases are rare, and in the majority the disease is a focal lesion more

or less extensive at some level in the dorsal or cervical cord, and the degeneration in the lateral columns is secondary. The evidence of the latter form is afforded (1) by the circumstance that the symptoms came on, in the first instance, suddenly or rapidly, primary sclerosis being gradual in onset, and a lesion which occurs in short time is always "focal"; (2) the evidence which may generally be discovered that there has been at some time, or is in some region, damage which extends beyond the lateral columns. The proof of this is the implication of sensation, or the interference, at the level of the lesion, with the central functions of the cord. We are only justified in suspecting a primary sclerosis of the lateral columns when we can find no such evidence or history of a wider focal lesion, and when the affection came on very gradually; and we can only feel *sure* that it exists when the arms become affected in the same manner as the legs, and after them. We must remember also that descending lateral sclerosis, with secondary spasmodic phenomena in the limbs, may also result from damage to the motor tracts above their decussation—in the medulla, the pons, or the motor parts of the cerebral hemispheres. It occasionally results from bilateral damage to the surface of the brain during difficult birth.

Certain lesions may damage the motor tracts slightly, and impair conduction in a peculiar way, apparently rendering it unequal in different fibres. As a consequence, the muscular action is disproportionate in different muscles, and instead of a balanced co-ordinated movement, we have an unbalanced jerky movement. This is seen especially when irregular islets of sclerosis affect the cord—disseminated or insular sclerosis; and according to the researches of Charcot it appears that this irregular conduction is the result of the unequal wasting of the medullary sheaths, the axis-cylinders remaining. A precisely similar symptom may result from pressure on the motor tract—as by a growth. Not rarely this "disseminated" or "insular" sclerosis, in one region, is combined with a system-degeneration in another. An occasional combination, for instance, is the jerking movement (from cervical insular sclerosis) in the arms, and ataxic inco-ordination in the legs (from lumbar posterior sclerosis). Or with the jerky inco-ordination in the arms there may be weakness with spasm in the legs from lumbar lateral sclerosis). In the latter case it is probable that the lateral sclerosis is simply "descending," the result of the damage to the pyramidal tracts higher up by the insular sclerosis. It must be remembered that insular sclerosis sometimes causes merely loss of power, and equal, not irregular, impairment of conduction, especially when it occurs in the dorsal region. In such a case we may be unable to distinguish its symptoms from those of a diffuse, widely-spread degeneration.

2. *Posterior Columns.*—In disease of the posterior columns there is interference with co-ordination without loss of power; excentric pains, impaired sensation, and diminution of reflex action, in consequence of the implication of the sensory roots. All these symptoms depend on disease of the postero-external columns (posterior root zone).* Disease of the postero-median columns gives rise to no known symptoms.

The posterior columns may be damaged by any pathological process; they are frequent seats of primary degeneration (sclerosis), the condition which constitutes the common form of locomotor ataxy. The symptoms of this disease usually present the following order—loss of the myotatic contractions, especially of the knee-jerk, pains, inco-ordination, diminution of sensation, loss of sexual power, and of the reflex-action from the skin (which may in the early stage be increased), affection of the sphincters, and occasionally interference with the nutrition of bones and joints.

There is no loss of motor power or wasting as long as the disease remains limited to the posterior columns. It may, however, extend forwards into the anterior cornua, causing muscular atrophy and weakness to be conjoined with the ataxy. Or the lateral columns may be affected at the same time as the posterior: we then have weakness as well as ataxy, but no wasting. The disease of the lateral columns causes, as I have just stated, increase of the muscle-reflex action, and this increase may thus co-exist with inco-ordination, the damage to the posterior roots being slight, perhaps absent, in these cases (see p. 36). Thus we may have the anomaly of ataxy with actual loss of power, excess of the knee-jerk instead of its loss, and the front-tap contraction obtainable, and even the foot-clonus.

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* It is to be noted, however, that recent researches, especially those of Pierret and Déjerine, have shown that there is frequently an independent degeneration of the peripheral sensory nerves. The extent to which the symptoms of the disease depend on this is at present undetermined. It does not appear to be invariable, and the effect is probably the same, whether the nerve-fibres are damaged at the periphery or in the posterior columns of the cord.

Associated with primary degeneration of the posterior column are certain other symptoms due to simultaneous degeneration elsewhere. Of these the most important are loss of reflex action of the iris to light, which is extremely common, loss of accommodation, which is rare, and optic nerve atrophy, which is occasional.

An important fact to remember, regarding the posterior columns, is their proneness to degenerate: they recover less readily, and degenerate more readily, than any other structure in the cord. A lesion in one spot may set up a degeneration which ultimately involves them in their whole extent. Damage affecting the whole thickness of the cord may pass away from the rest, and persist in the posterior columns, and even spread there. In such a case we have ataxy succeeding loss of power. Movement returns, but without co-ordination.

3. *Anterior Cornua.*—The anterior cornua contain the motor nerve-cells, which, as I have said—(1) influence the nutrition of the motor nerve-fibres proceeding from them, and consequently that of the muscles; (2) constitute a link in the path of the voluntary impulse from the brain to the muscles; (3) form part of the reflex loop, probably also of the reflex centre, with which the muscles are connected.

Hence we have, as the result of disease of the anterior cornua—(1) degeneration of the motor nerves and wasting of the muscles; (2) loss of voluntary power, *i.e.*, paralysis of those muscles; (3) interference with, or arrest of, all the reflex actions in which these muscles take part.

The extent of these symptoms, whether they are unilateral or bilateral, affect many muscles or few, will depend strictly on the extent of the disease in the spinal cord.

Of the three symptoms, the muscular wasting is incomparably the most important. Paralysis may result from disease elsewhere in the motor tract, *e.g.*, disease of the lateral column higher up. Loss of reflex action may depend on disease elsewhere in the reflex loop, *e.g.*, disease of the sensory fibres in or outside the cord. But muscular wasting is due only to a lesion of the motor cells, or to a lesion of the nerves cutting the muscles off from the influence of these cells. In most cases we are able to exclude the latter (by indications presently to be mentioned): the state of muscular nutrition comes thus to be of the highest importance as indicative of the state of the anterior cornua of the cord. To learn their condition further, we ascertain the electrical excitability of the nerves and muscles, according to the principles already laid down.

Whenever we find wasting, and infer that there is disease of the anterior cornua, we have next to observe whether the weakness and wasting are proportioned, *i.e.*, whether the weakness is only such as the affection of the grey matter will account for, or whether it is in such excess as to indicate other disease in the motor tract.

In acute diseases of the anterior cornua, paralysis precedes wasting. The sudden interruption of the motor path causes immediate loss of power. Wasting of muscles succeeds the degeneration of the motor nerves, occurring a week or ten days after the loss of power. In chronic diseases the wasting and weakness come on together.

Chronic disease of the anterior cornua is often combined with disease of the lateral (pyramidal) columns similar to the descending degeneration. Charcot believes that in these cases the degeneration in the lateral column is primary, its symptom, muscular rigidity, preceding the symptom of the cornual disease, muscular wasting, and he terms the affection "lateral amyotrophic sclerosis." It is possible, however, that this position will need reconsideration, and that the degeneration in the lateral columns is, sometimes at least, secondary to, or simultaneous with, the disease in the cornua. It often extends, however, beyond the fibres related to the degenerated cornua, and so may cause weakness and spasm in the limbs below the seat of the muscular atrophy. Thus we have wasting in the arms, and weakness with spasm in the legs, and even, as I have seen, wasting in the shoulder muscles, and weakness without wasting in the hands.

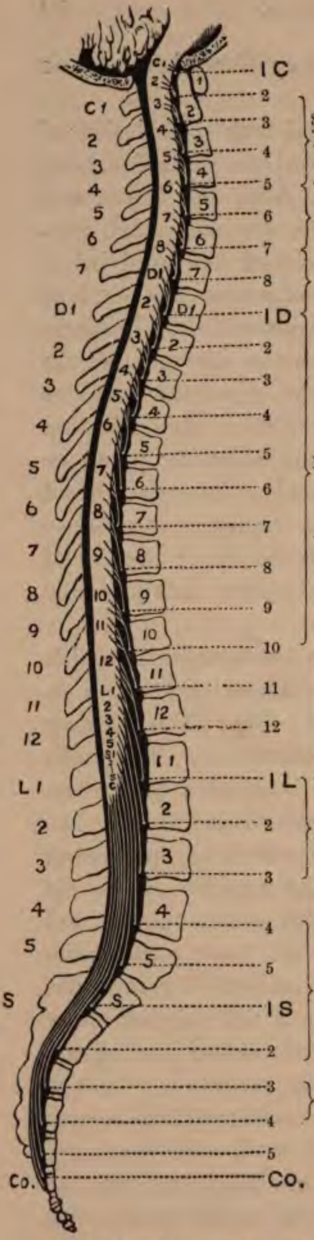
A lesion of the anterior cornua never, *per se*, affects sensation. Acute lesions in this situation may, however, disturb adjacent sensory parts (posterior cornu or sensory tract), and so cause "excentric" pains, often rheumatic in character. Actual loss of sensation, with wasting, points, especially if irregular in distribution, to damage to the nerve-roots outside the cord, and therefore to disease of the meninges rather than of the cord itself.

4. *Unilateral Lesions.*—These interfere with the conduction of the motor impulse on the same side as the lesion, and so cause weakness in one side, "hemi-paraplegia" or "spinal hemiplegia," and often descending unilateral sclerosis with its symptoms in the affected leg. Whether there is weakness of the other leg (if the lesion is strictly unilateral) will depend on the number of pyramidal fibres, which in the "direct pyramidal tract," have not decussated at the seat of the lesion; and this varies, as we have seen, in different individuals. It must be remembered, however, that in unilateral lesions, the opposite half of the cord is often slightly damaged, and the symptoms are therefore rarely limited to one leg. Sensation is affected on the opposite side to motion, but not quite up to the level of the lesion, because the decussation of the sensory tract is not immediate, but occurs a little above the place at which the nerves enter the cord. Sometimes, however, sensation is affected on the same side as motion. This is often the case when the paralysis affects the leg only, and probably the lesion is, in such

cases, so placed as to impair the sensory fibres before their decussation.

5. *Total Transverse Lesions.*—A total transverse lesion of the cord, at any level, however limited in vertical extent, separates all parts below the lesion from the brain, and hence, so far as will and perception are concerned, produces the same effect as if the whole of the cord below the lesion were destroyed. A section across the cord in the middle of the cervical enlargement, for instance, paralyses all parts below the neck with the exception of the diaphragm. Hence the extent of the paralysis indicates only the upward limit of the lesion. This is also indicated by the position of the girdle-pain and radiating pains, or zone of hyperæsthesia, which are due to the irritation of the sensory roots in the lowest part of the upper segment—an important indication when the lesion is in the dorsal region, where the precise limitation of motor weakness may be recognized with difficulty.

It is important, however, to know the symptoms which occur in disease at different levels. These are shown in the accompanying diagram and table (Fig. 14), and may be understood from the following description. The indication of the upper level of the lesion is afforded by the loss of the motor and sensory functions, shown in the first two columns. The lowest nerves supply the anus and perineum. The nerves which supply the skin and muscles of the leg and foot arise from the 1st to the 3rd sacral nerves, and are damaged by a lesion involving the lower part of the lumbar enlargement. We must remember, however, that the skin on the inner side of the leg is not supplied from this source, and so may escape when the outer part of the leg and back of the thigh have lost sensation. In the middle of the lumbar enlargement, we have the nerves arising which enter the lumbo-sacral cord, and these are probably destined for the flexors of the knee, and for the hip muscles which are supplied by the sacral plexus, the glutei, the quadratus, and gemelli, and the skin of the lower part of the gluteal region. These parts then will be



MOTOR.	SENSORY.	REFLEX.
St.-mastoid Trapezius	Neck and Scalp	
Diaphragm	Neck and Shoulder	
Serratus		
Shoulder mus.	Shoulder	Scapular
Arm mus.	Arm	
Hand mus. (ulnar n. lowest)	Hand	
Intercostal Muscles	Front of Thorax	Epigastric
	Ensiform area	
Abdominal Muscles	Abdomen (Umbilicus 10th)	Abdominal
	Buttock, upper part	
	Groin and Scrotum (front)	
Flexors, hip	Thigh outer side	Cremasteric
Extensors, knee	Thigh front	*Knee-jerk*
Adductors hip		
	Thigh inner side	
Abductors hip	Leg, inner side	
	Buttock, lower part	Gluteal
Extensors(?) hip		
Flexors, knee(?)	Back of Thigh	
Muscles of leg moving foot	Leg and Foot except inner part	*Foot-clonus*
		Plantar
Perineal and Anal muscles	Perineum and Anus	
	Skin from coccyx to anus	

FIG. 14.—DIAGRAM AND TABLE SHOWING THE APPROXIMATE RELATION TO THE SPINAL NERVES OF THE VARIOUS MOTOR, SENSORY, AND REFLEX FUNCTIONS OF THE SPINAL CORD. (*From anatomical and pathological data.*)

paralysed by disease in the middle of the lumbar enlargement, while the muscles and skin in front of the thigh are unaffected. The latter suffer when the disease affects the upper part of the lumbar enlargement, the origin of the anterior crural (rectus, etc.), and obturator (adductors). The skin on the upper and outer parts of the thigh loses sensibility, with the part adjacent to the scrotum, and in the groin, only when the disease damages the highest part of the lumbar enlargement, from which the first three lumbar nerves arise, and then the flexors of the hip become paralysed. In proportion as the disease is higher in the dorsal region, we have the symptoms ascending higher up the trunk, and marking accurately the height of the lesion by the loss of cutaneous sensibility, and by the impairment—first, of the abdominal muscles, and then of the intercostal muscles. The umbilicus corresponds to the 10th dorsal nerves, and the ensiform area to the 6th and 7th. When the disease reaches the lowest part of the cervical enlargement (the 1st dorsal nerves), we have the first symptoms in the upper extremity; but these are not, as might be expected, in the muscles moving the shoulder joint, but in the hand. The first numbness is complained of in the little finger, and the first weakness is in the intrinsic muscles of the hand. Ascending higher, the symptoms pass up the arm with some uniformity, and without respect to nerve distribution. When the middle of the cervical enlargement is reached (the 5th, 6th, 7th cervical) the shoulder muscles and the serratus magnus become paralysed, and there is general loss of power and sensation and anæsthesia. Above the level of the 6th pair, the trapezius and sterno-mastoid become somewhat weakened, for the fibres of the spinal accessory which supply them undoubtedly arise in part from this region of the cord. At the 4th and 5th cervical the lower part of the neck becomes anæsthetic, and the diaphragm ceases to act. Here our localization might cease, for total transverse lesions at this spot necessarily cause death. For a little time the sterno-mastoids and scaleni can still get air into the chest, but not in sufficient amount to maintain life for more than a few days. But limited lesions may occur higher up, and then we have complete powerlessness of the muscles moving the head, upper part of trapezius and sterno-mastoid, and other muscles attached to the occipital bone, and interference with sensation in the neck and parts of the head, which are not supplied by the 5th nerve.

The extent downwards of the lesion, its vertical extent, is thus not indicated by the impairment of its conducting functions, the motor or sensory paralysis; and to learn *this* we have to examine the functions of the cord as a central organ, and to ascertain how far they are impaired in the paralysed region—to examine especially muscular nutrition and reflex action. The state of muscular nutrition and irritability indicates how far the anterior cornua are impaired, and the latter shows, as I have explained (p. 40), whether they are involved in the primary lesion or are affected secondarily. The relation of the several groups of muscles to the cord is shown in the first column of the table. The integrity of reflex action indicates the integrity of the reflex loops, and the study of the superficial reflexes of the trunk is especially instructive in this respect. The series of reflexes, and the relation of each to the cord, are shown in the third column of the table; the myotatic contractions are printed in italics in the position which corresponds to the centres, the influence of which is essential for their production. Excess of superficial reflex action indicates withdrawal of the cerebral controlling influence of the reflex centres, and marked excess of the muscle-reflexes suggests the existence of a descending degeneration in the lateral columns.

IV.—INDICATIONS OF NATURE OF DISEASE: PATHOLOGICAL DIAGNOSIS.

The last part of our subject remains for consideration—the elements of the pathological diagnosis, by which, having ascertained the seat of the lesion, we endeavour to learn its nature. To do this, we attend, first, to the way the symptoms come on and develope; secondly, to the position and distribution of the lesion; thirdly, to any causal or associated conditions which may be present.

We may group the primary morbid states into the following forms:—

(*a*) Vascular lesions; rupture of vessels, causing hæmorrhage; occlusion of vessels, from thrombosis or embolism (the latter being very rare).

(*b*) Inflammation; "myelitis," acute or chronic, the former causing softening. It is common to call all forms of softening "myelitis"; we do not yet know how far they are originally inflammatory, or are set up, as in the brain, by vascular occlusion. Some chronic inflammations are not attended by softening.

(*c*) Degeneration and "sclerosis," in which the nerve-fibres waste, and the connective tissue (neuroglia) overgrows.

The term "sclerosis" is inaccurate etymologically, since the part altered by increase of connective tissue elements is often softer than normal, but the term is firmly established. In some cases the change appears to commence in the nerve-fibres, in others in the connective tissue. Some forms of degeneration pass by graduations into chronic inflammation (here as elsewhere), and the term "chronic myelitis" is sometimes applied to the slow degenerative forms. On the other hand, the condition of "sclerosis" may result from inflammation. The term is thus used in two senses, to indicate a pathological process, and a pathological condition which may result from more than one morbid change. Here the term will be used, when unqualified, to designate the process.

It is most important to remember that degeneration and sclerosis are not identical terms. Primary degeneration of the nerve-fibres is followed, after weeks or months, by overgrowth of the interstitial tissue, which takes their place.

(*d*) Pressure from without, by inflammatory swelling of meninges, or by displaced bones, or by growths.

(*e*) Growths in the cord itself.

I. We have first to consider how far these several lesions can be distinguished by their onset, *i.e.*, by the time occupied in their development to a considerable degree of intensity. According to this, we may divide them into five classes: those in which the onset is *sudden*, instantaneous or nearly so; *acute*, occupying a few hours to a few days; *subacute*, developing in one to six weeks; and lastly, the *chronic* cases, which may be divided into those occupying six weeks to six months, and those occupying six months and upwards in their onset.

I have endeavoured to show the common relation of the lesions to these several courses in the following table:—

	Onset.	
	Sudden (*few minutes*) . .	Vascular lesions.
	Acute (*few hours or days*) .	
Pressure or Growths	Subacute (*one to six weeks*) .	Inflammation (myelitis.
	Chronic (*six weeks to six months*).	Degeneration (sclerosis).
	Very Chronic (*six months and upwards*)	

A lesion of sudden occurrence, developing symptoms in the course of a few minutes, is almost always vascular; commonly hæmorrhage, perhaps sometimes vascular obstruction. But a vascular lesion may occupy a somewhat longer time in development—a few hours or days. In acute and subacute inflammation the symptoms come on in the course of a few hours, a few days, or a week or two. Chronic inflammation occupies from a few weeks to a few months. Degeneration, in which there is no adequate evidence of any inflammatory process, occupies many months, or it may be years. The symptoms produced by growths or simple pressure (traumatic causes excluded) are never sudden or very acute, and rarely, if ever, very chronic, the time occupied by the development of the symptoms varying, according to the nature of the cause, from a fortnight to six months.

It is necessary to consider, however, not merely the whole time occupied by the development of the disease, but also the uniformity of its course. Two or more morbid processes may concur. An initial myelitis, for instance, may lead to a secondary degeneration; and, on the other hand, in degenerated tissues sudden vascular lesions occasionally occur. Pressure often produces local myelitis, which may be very acute in its development. Cancer of the vertebræ, for instance, usually causes rapid myelitis. The whole course of the disease must be ascertained before an inference is drawn.

The onset and course of the symptoms thus sometimes enable us to decide at once that a lesion is of a given character, as that one which occurs instantly is vascular, or that one which takes years for its development is degenerative. More frequently they enable us to exclude certain morbid processes, and to restrict the possible lesion to two or three forms. For instance, a lesion which comes on in the course of a few hours must be either vascular or inflammatory. Between these we have to decide by attention to other indications.

II. In actual diagnosis it is convenient to consider next the indication afforded by the position and distribution of the disease. We consider what diseases occur in this situation, and then which of them have the mode of onset which has been ascertained. As I said at the outset, this indication is only to be employed in subordination to a careful study of the mode of onset and course.

The grey matter of the cord is the most frequent seat of hæmorrhage. Either grey or white substance may be the seat of inflammation or of degeneration. In young children inflammation is much more common in the grey matter than in the white. Pressure or growths usually first affect the white columns, but may afterwards involve the grey matter.

The affections called "system-diseases," in which one system of structure is affected through a wide vertical extent of the cord, are commonly degenerative in nature: such are lateral sclerosis, posterior sclerosis (locomotor ataxy), the change in the anterior cornua which leads to progressive muscular atrophy (anterior cornual degeneration). These processes probably begin in the nerve elements. On the other hand, lesions which have a limited vertical extent —"focal lesions"—are commonly the result of processes which may be either acute or chronic, but begin outside the nerve elements, in the connective tissue, vessels, etc. Such are hæmorrhages, foci of myelitis, spots of "insular" sclerosis, growths, and pressure from without.

But this distinction cannot be employed except after due consideration of the mode of onset. Scattered acute focal lesions, for instance, may be widely distributed in the same structure, and produce symptoms limited to certain functions, but of wide extent, and simulating—indeed, constituting—a "system-disease." Thus I have seen sub-acute symmetrical myelitis of the anterior cornua in the lumbar and cervical enlargement cause paralysis and atrophy in all four extremities, the upper parts of the limbs being normal. Again, a small focal lesion may be limited to one structure, and cause symptoms confined to one function. Thus we may have an anterior cornual myelitis, or a columnal myelitis, lateral or posterior, giving rise to limited symptoms—local muscular atrophy, unilateral paralysis, or local ataxy. Lastly, many "focal lesions" may give rise to secondary system-degenerations. A focus of myelitis in one lateral column may cause descending degeneration in the whole lateral column below, with its attendant spasmodic symptoms. Indeed, so true is this, that, as we have seen, lateral sclerosis is more often secondary to a limited focal lesion than primary. In all these cases, however, attention to the mode of onset will prevent error.

The combination of mode of onset with seat of lesion sometimes helps us in a more direct manner, especially in the case of growths and compression. The characteristics are their limited vertical extent, gradual onset, and slow invasion of parts adjacent to that first affected, on the same level; one leg, for instance, is affected, and then the other.

Indication of disease outside the cord, irritation of certain nerve roots, causing severe local pain, often precedes the symptoms of compression and is an important aid to diagnosis. It shows the existence of a morbid process outside the cord before the cord is involved. But we cannot use even this indication except in dependence on the mode of onset. A disease, as a growth outside the cord, may not only compress the cord, and cause slow loss of power; it may excite inflammation and cause rapid palsy.

There is a rare form of paralysis, in which the functions of the cord are progressively impaired from below upwards, until, in the course of a few days, death results from interference with respiration. In these cases of "acute ascending paralysis," as they are called, no lesion of the cord has usually been discovered, and their exact nature is unknown.

III. The last element in the pathological diagnosis is the detection of any influence which can be regarded as the cause of the disease in the spinal cord, or any associated condition which may indicate an active morbid process. We have seen that the mode of onset may help us to limit the disease to certain possible forms of lesion: the distribution of the affection may render it probable that it is one or other of these forms; and the detection of a cause of disease of the spinal cord, and the knowledge of the lesions which that cause produces, may help us to fix the nature of the lesion still further. It is important, therefore, in diagnosis, to be aware of the several effects of the common causes of spinal disease.

1. *The Age of the Patient.*—In young children acute myelitis is the most frequent lesion, and the grey matter is usually the chief seat of the disease.

2. *The State of the Vascular System.*—The conditions which favour hæmorrhage are of far less diagnostic value with regard to the spinal cord than with regard to the brain. Conditions of mechanical congestion—heart disease, emphysema, etc.—favour degenerative changes and also, probably, thrombosis. The state of the vascular system which is associated with chronic kidney disease undoubtedly favours degenerative changes in the cord, the occurrence of which has been demonstrated by Sir William Gull and Dr. Sutton.

3. *Scrofula* commonly causes spinal disease by leading to disease of the bones of the spinal column; and the evidence of this, local tenderness or irregularity of the vertebral spines, or actual curvature, is of the highest diagnostic importance, and careful and repeated examination of the bones should never be neglected in cases of obscure spinal disease. There is, perhaps, no error in diagnosis which is more frequently made, or which results in graver errors in treatment, than the non-recognition of disease of the spinal bones. It is important to remember that the damage to the cord may occur before the signs of bone disease are distinct: hence the importance of *repeated* examinations.

In bone disease the cord suffers in at least four different ways:—(*a*) By pressure from the inflammatory swelling of the bone or inflammatory products without curvature. The effects of the pressure may lessen as the curvature comes on. (*b*) By pressure in consequence of the displacement, the bony canal being narrowed by the angular projection of the bodies over which the cord is stretched. (*c*) By secondary chronic inflammation, with thickening, of the dura mater and tissue outside it, compressing the cord.

(*d*) By inflammation extending through the membranes to the cord, or set up in the cord by the compression. Hence we cannot, because we find evidence of bone disease, immediately conclude that the cord is pressed upon by the displaced bone. We must investigate the mode of onset of the symptoms and their character, and infer from these the character of the disease of the cord according to the rules now given. The most common mechanism is compression by products of inflammation outside the dura mater, and by the thickening of this membrane.

In recognizing bone disease it must be remembered that not only may there be no angular curvature until long after the cord has suffered, but there may not even be irregularity of the vertebral spines. There are often pain and local deep tenderness to be elicited. In the resulting paraplegia the excess of the cutaneous reflexes is often an early and conspicuous symptom, and spots of anæsthesia at the level of the bone disease, due to pressure on nerves, may sometimes be found, and give important help in diagnosis.

4. *Syphilis.*—The methods by which syphilis causes disease of the cord, which are universally recognized, are—

(*a*) The growth of syphilomata springing from the connective tissue, the membranes, or tissue in the fissures, and invading the cord. In these cases we have symptoms varying in character according to the position of the growth, and similar to those produced by other limited lesions, but always of gradual onset.

(*b*) By chronic meningitis, with thickening and pressure on the nerves, and sometimes on the cord also. The characteristic symptoms depend upon the damage to both motor and sensory nerves, that of the former cutting off the muscles and peripheral nerves from the influence of the motor nerve-cells, and hence causing muscular atrophy, very similar to that due to disease of the grey matter, but differing by its association with scattered areas of diminished sensitiveness of the skin. The interference with the reflex loops abolishes reflex action in the part; but if the damage is confined to the upper part of the cord, and the cord itself is pressed upon, there may be an excess of the reflex action on the lower part.

(*c*) Syphilitic disease of vessels may *probably* lead to acute softening, similar to that in the brain. Syphilitic subjects may become suddenly paraplegic, and it is possible that it is by this mechanism, although the fact does not at present rest on post-mortem evidence.

All the above lesions originate in the adventitial structures. There is, however, a considerable mass of evidence to show that (*d*) diseases which originate in the nerve elements and neuroglia, more or less inflammatory or degenerative in character, may be a late effect of syphilis. I have found, for instance, disseminated foci of chronic myelitis, affecting chiefly the periphery of the cord, throughout the dorsal region, in a syphilitic woman, and two similar cases have been observed by Pierret. It is probable that this form of chronic myelitis is usually syphilitic.

Symptoms of acute myelitis sometimes occur in syphilitic subjects, and the myelitis has been regarded as due to the syphilis, but the evidence of this is at present insufficient.

The majority of cases (about 70 per cent.) of locomotor ataxy, primary posterior sclerosis, occur in individuals who have had syphilis many years before.* Anterior cornual degeneration (progressive muscular atrophy) sometimes occurs after constitutional syphilis, and so also do the symptoms associated with sclerosis of the lateral columns. In these cases of degenerative disease it does not appear, as far as we can tell, that the anatomical process presents any recognizable difference from that which occurs as a result of other causes; and it is possible that the influence to syphilis, although effective, may not be direct, *i.e.*, the disease is due, in part at least, to the preceding syphilis, although it is not syphilitic in nature. One consequence of syphilis may be to cause a neuropathic tendency, in which these diseases are gradually developed.

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* See "Syphilitic Neuroses," "Brit. Med. Journal," March, 1879. A similar statement had been expressed before by Fournier, and since has been made by Vulpian and Erb. I have given their statements in a paper on the subject of "Syphilis and Locomotor Ataxy," in the "Lancet" for January, 1881. It is not suggested that syphilis is the cause in this proportion; in some the coincidence of the two diseases may be accidental. The facts seem to justify the assertion that half the patients would not suffer from ataxy had they not previously suffered from syphilis.

Although not strictly a fact of etiology, I may mention that the result of treatment often affords an important corroboration of the diagnosis of syphilitic disease. If symptoms, which we have reason to suppose are due to syphilitic disease, improve rapidly when iodide of potassium or mercury is given, the diagnosis is strongly corroborated.* But the converse of this is not equally true. A disease may be due to syphilis, and no improvement be obtained from specific treatment. It must be remembered that as regards (*a*), (*b*), and (*c*), the syphilitic disease causes symptoms by producing changes in the nerve elements, softening, degeneration, etc., which are not in any way syphilitic, but are such as would result from adjacent disease of any other nature. Under some conditions (of intensity, duration, etc.), the recovery of the nerve-tissue may be impossible, even though the syphilitic adneural disease be completely removed. Further, the diseases of the last class (*d*) are not, except in the earliest stage, benefited to any marked extent by anti-syphilitic treatment.

5. *The exciting causes* of disease of the spinal cord sometimes afford diagnostic indications. Exposure to cold may cause acute symptoms, commonly due to inflammatory softening—sometimes focal, sometimes diffuse; and in the latter case often accompanied by symptoms of meningitis. It may also cause hæmorrhage. It is especially effective in women at the menstrual period. Repeated exposure may lead to degeneration, especially in the grey matter.

Acute specific diseases, as typhoid fever, are occasionally followed by spinal symptoms, due to changes which are probably of the nature of subacute inflammation. It is very common for a patient, after typhoid fever, to suffer for a long time, sometimes permanently, from weakness of the legs; and occasionally during the course of the disease acute symptoms, as those of anterior cornual myelitis, may occur.

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* Always provided the symptoms are not such as tend to lessen spontaneously. I do not mention this exception in the text, because, important as it is, it has less application to the syphilitic diseases of the spinal cord than to those of the brain.

Sexual excess is a more common cause of transient functional weakness than of organic disease.

Traumatic influences are frequent causes of cord disease. The cord may be directly pressed upon and damaged by displacement or fracture of the vertebræ, or a severe concussion may be followed by slow paralysis at an interval of a few days or weeks. In such a case, occurring after a railway accident, I have found numerous minute foci of chronic inflammation, most abundant in the grey matter. Sometimes a still longer interval elapses between the injury and the paralysis. In such cases a growth or patch of sclerosis appears to be set up by the injury, although years may pass before the symptoms reach a considerable degree of intensity.*

These, then, are the chief etiological facts, which, taken in conjunction with mode of onset and distribution, enable us to form an opinion regarding the nature of the lesion.

To sum up: In examining a case of disease of the spinal cord, the method should be briefly as follows:—First, endeavour to ascertain the exact seat of the lesion; note how far the several conducting functions of the cord are impaired, and the highest level of the impairment; then ascertain the condition of the central functions, especially muscular nutrition and irritability, and reflex action, first in the part below the level at which conduction is impaired, and secondly at the supposed level of the lesion; and in this way you may infer, without much difficulty, what is the extent of the lesion transversely and vertically. In the next place endeavour to ascertain its nature by considering—first, how the symptoms came on and developed; secondly, which of the lesions having this mode of onset and development occur in the region affected; and thirdly, which of them are produced by the cause or causes to which the disease is apparently due.

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* An instructive instance of the way in which the results of an injury of the head may cause both growths and arterial disease, and, years later, both chronic and acute symptoms, will be found recorded in the author's "Medical Ophthalmoscopy," Case 4, p. 248.

This process of diagnosis may seem somewhat elaborate, and, no doubt, a practised observer does not always consciously go through it. But, in most cases, if he wish to avoid error, he goes through it unconsciously, and no step can be with safety dispensed with. We may thus, in almost all cases, arrive at an exact diagnosis of the seat of the disease, and, in a large number of cases, of its nature also. There are, however, some cases with respect to which the diagnosis of the nature of the lesion can be approximate only, although we can always limit it to one or two possibilities.

It will be observed that I have said nothing of "anæmia of the cord," of "hyperæmia of the cord," or of "reflex paralysis." In current descriptions of the symptoms of these conditions, I cannot help thinking that a vigorous scientific imagination has contributed much more than observation has supplied. The only practical knowledge of the effects of anæmia and hyperæmia of the cord, is, that they seem capable of causing such disturbance of the sensory structures as reveals itself in subjective sensations of tingling, pins and needles, and the like, and perhaps also some impairment of motor conduction. A large number of authorities here and abroad are sceptical as to the existence of such a condition as "reflex paralysis," *i.e.*, a paralysis due to the effect on the centre of some peripheral irritation, disappearing when this was removed. Although our modern knowledge of the various phenomena of inhibition and reflex action renders such a paralysis *à priori* even probable, it is certain that the theory has been extensively misapplied.

Spinal Meningitis.—The object of this lecture has been to explain the principles of the diagnosis of diseases of the cord itself. But it may be well to allude briefly to the diagnosis of spinal meningitis. Of acute meningitis I need say little. The acute symptoms, spinal pain, and severe spasms, are well known. Chronic spinal meningitis, however, is a disease regarding which current opinion has curiously changed during the last fifteen years. A large number of symptoms were assigned to chronic meningitis which we now know have nothing to do with that pathological state. I have mentioned that to it the symptoms of weakness with chronic spasm, "spasmodic paraplegia," were ascribed. But we now know that these are due to alterations within the cord, and are independent of any meningitis. The only symptoms which are usually due to this condition are those which result from the involvement of the nerve-roots in their passage through the diseased membranes. The roots are irritated by the adjacent inflammation. The meninges frequently become much thickened, and by this thickening the nerve-roots are often greatly damaged. The irritation affects first the sensory roots, causing "excentric" pains and hyperæsthesia, to which are often added areas of anæsthesia here and there, due to the greater damage of some nerve-roots. The affection of the motor roots causes symptoms similar to those of disease of the anterior cornua, but very irregular in distribution. The peripheral motor nerve-fibres, cut off from their motor cells, degenerate, and the muscular fibres waste, and present electrical reactions which vary according to the rapidity of the morbid process. Sometimes the nutrition of the skin suffers. There is frequently, in addition, pain in the back, from the lumbar to the cervical region, sometimes severe between the shoulders, and accompanied sometimes with rigidity of the vertebral muscles.

The chief conditions with which chronic spinal meningitis may be confounded are posterior sclerosis (locomotor ataxy) in which the sensory nerve-roots are implicated, and anterior cornual degeneration (progressive muscular atrophy). From the former it is distinguished by the absence of ataxy, from the latter by the irregular distribution of the symptoms, and from both by the existence of limited areas of anæsthesia, and of extensive spinal pain. It must be remembered that inflammation often affects the substance of the cord as well as the meninges, or the cord may be pressed upon by the thickened membranes, and so mixed symptoms may result.

A word on the subject of the nomenclature of diseases of the spinal cord. If we wish to obtain clear ideas, it is essential to use terms, where we can, which shall be pathological, and which shall be at once simple and descriptive. To obtain these, we must avoid the error, too common, of striving after extreme brevity. Names of morbid states, the meaning of which is obvious, are, even if somewhat longer, to be preferred to shorter expressions, the meaning of which is obscure. We are apt to associate with brief obscure names the idea of definite diseases. But if we would gain and convey exact ideas of the diseases of the spinal cord, we must endeavour to substitute the idea of morbid processes for that of definite diseases.

A simple and convenient system of terminology lies close to hand. We have in the spinal cord, the two cornua of grey matter and the three columns, lateral, anterior, and posterior. In each of these situations the various morbid processes already described may occur, and we have only to combine the terms indicating the place and the lesion to have a system of terminology already partly in use, and which will altogether suffice for our present needs. Thus we may have a columnal or a cornual myelitis, hæmorrhage, sclerosis, degeneration, or growth. We may have, for instance, an "anterior cornual myelitis," or, for shortness (since we cannot yet diagnose posterior cornual diseases), a "cornual myelitis;" or we may have a cornual degeneration. For anterior cornual myelitis, the term "tephro-myelitis" has been proposed by Charcot, and "anterior polio-myelitis" by Kussmaul. The latter term has obtained wide currency, but its meaning is much less obvious than that of "anterior cornual myelitis." The simpler system of nomenclature I have employed throughout this lecture, and it has probably been readily intelligible, although unexplained.

V.—THE DISTINCTION OF FUNCTIONAL AND ORGANIC DISEASE.

No term is more loosely used in medical writings than "functional disease." It is commonly employed, in regard to the nervous system, as a designation for those affections in which no morbid changes have been hitherto discovered, even with the microscope, and from which recovery is possible. Unfortunately, we have no other general term for these cases, and it is to be regretted that we are compelled to make a positive term connote negative characteristics. Strictly speaking, a functional disease is one which consists in a disorder of function without any preceding alteration of nutrition. The affections of the nervous system which can be included under this definition are very few. Most of the examples of purely functional disturbance of one part are the result of disease in some other part of the nervous system. In most cases of so-called functional disease, we must assume changes in nutrition. In some, these changes are probably primary; in others they may be secondary to the disturbance of function.

Hysteria is the most frequent cause of symptoms that are within the range of the spinal functions, and not due to organic disease. Hysterical symptoms of spinal type usually have the form of loss of power in the legs, "hysterical paraplegia;" and one of the most frequent problems in diagnosis is the distinction of this from organic disease. But more than one morbid condition is included under the term "hysterical paraplegia." In the most characteristic form of the disease there is not any affection, even functional, of the spinal cord. There is loss of power over the legs, because there is in relation to the legs the peculiar ungeared state of the volitional centres, which is at the root of all pure hysteric palsy. There is no disturbance of the central functions of the cord. Reflex action from the skin, and myotatic irritability, are normal. The muscles do not waste, although they may become somewhat flabby from disuse. Retention of urine may occur, but there is never incontinence, nor is there any affection of the sphincter ani. Sensation on the legs is almost always normal. Thus, all objective indications of an affection of the cord are absent. It is necessary to establish this negative fact before any weight can be allowed to the positive indications of the hysterical nature of the case. These are rather suggestive indications than positive symptoms. One of them is the presence or history of other unequivocal symptoms of hysteria, globus, loss of voice, hysteroid convulsions, and the like. Another is the mode of onset. Hysterical paraplegia is often excited by some emotional shock, such as an alarm. But it rarely comes on instantly, or reaches a high degree in an hour or two, except when it immediately follows a severe emotional shock. Usually its development occupies several days or weeks, and it is often preceded by occasional attacks of momentary weakness in the legs. When a considerable degree of weakness comes on quite suddenly there have been usually such preceding transient attacks of slighter loss of power. A third indication is derived from the character of the weakness. It is very rarely absolute. Some power usually remains. The patient can move the legs, but cannot stand. Moreover, there are two peculiarities in the manner in which the legs are moved which are, perhaps, more significant than any other positive symptom. But the full power which can be exerted is not put forth at once. By continued effort and repeated urging much more force can be evoked ultimately than at first. Thus the patient, lying in bed, is told to raise the foot. She does so, slowly, for about six inches, and says she cannot get it any higher. Nevertheless she holds it there, and if urged ultimately raises it higher, a foot or eighteen inches from the couch. The second is that if the patient tries to exert force with a given group of muscles, the opponents of those muscles are put in action at the same time and in undue degree. Thus, if the knee is flexed, and the patient is told to try to extend it, the flexors are put in action, as well as the extensors, and prevent the movement. Resistance to passive movement is often hesitating and jerky. Occasionally a movement, at first steady, becomes modified, in a few minutes, by tremor, usually quick but variable, now fine, now coarser, and with quick sudden jerks. It has been mistaken for the spasm of disseminated sclerosis, but differs in not being uniformly wild and irregular. The tendency to contract other muscles than those which effect the desired movement, is often associated with an inability to relax the muscles voluntarily. This may prevent the knee-jerk being obtained. The flexors of the knee contract and prevent any movement when the patellar tendon is struck. I believe that it is this, and this alone, which has led to the assertion that the knee-jerk is sometimes lost in hysterical paraplegia, or that it varies, and can be obtained at one time and not at another. There is rarely anæsthesia. These several indications are separately of little significance; they derive value from their combination.

In another class of cases there is, in addition to the above symptoms, distinct indication of slight disturbance of the functions of the spinal cord itself. There is spinal tenderness, apparently due to a neuralgic state of the spinal membranes or ligaments. Pain in and about the spine is often complained of, and is increased by movement, but it is never unilateral, passing round one half of the trunk, as in organic disease. There is a slight increase of myotatic irritability in the legs. The knee-jerk is excessive; the rectus contraction can readily be produced by tapping the depressed patella. The front-tap contraction in the gastrocnemius may be obtained, and a "spurious foot-clonus" may occur when the ankle is passively flexed. This spurious clonus results, as already described (p. 32) from a voluntary and variable contraction in the calf muscles. There is never a regular persistent clonus, except when there is persistent hysterical contracture (to be presently described), a much rarer condition in hysterical paraplegia than in hysterical hemiplegia.

This morbid state of the central functions of the cord is probably, in some cases at least, the result of the complex combination of neuropathic tendencies, which is called hysteria. The clinical history of this disease affords many examples of the affection of lower centres, excited by emotional causes, but running a course to a considerable extent independent. Nutritional changes doubtless follow the disturbed function, and one case recorded by Charcot suggests that, after years, the changes in nutrition may attain the degree of visible structural alterations. But in many cases of hysterical paraplegia the change in nutrition is to a large extent, often altogether, removable by judicious treatment directed to the strengthening of the will, improvement of physical health, and the removal of the irritable state of the spinal cord.

In other cases the disturbance of the cord has an independent origin. Many weakly women, who are not hysterical, suffer from symptoms which indicate slight impaired action of the cord. They are bad walkers, soon tire, and when tired suffer pain in the spine. The muscles of the legs are flabby, sometimes very thin; the knee-jerk is excessive. This condition is often left after prostrating diseases, such as typhoid fever, repeated child-bearing, prolonged anemia from any cause, and may be permanent. If such women are, or become, the subjects of hysteria, the spinal weakness determines the direction in which symptoms develope that are of ideal origin. It is often difficult to distinguish these cases from those last described. I believe, however, that those in which the disturbance of the central function of the cord is secondary to hysteria are far less common than those in which slight spinal weakness or pain in the back precedes the hysterical disturbance and determines it, and may endure after the volitional defect is removed. Often both may be due to a common cause, which impairs general health and lowers nervous tone.

These cases, in which volitional defect is combined with slight over-action of the spinal centres, give rise to considerable diagnostic difficulty, unless the complexity of the pathological condition is duly recognized.

In cases in which there is rigidity of the legs, the question arises whether there is true spasm or hysterical contracture. The problem is the more difficult, because in each condition the limbs are usually extended, and in each there may be a distinct foot-clonus. This may be developed in hysterical contracture, as it is in health when the calf-muscles are long contracted. But in the vast majority of cases attention to the following points will decide without difficulty the nature of the case. In hysterical contracture the muscular spasm is greatest at the extremity of the limb. The ankle-joint is extended, so that the dorsum of the foot is in the line of the tibia, and the foot is usually inverted. Any attempt to alter the position is resisted, and if the contracture is partially overcome the rigidity continues. It can be ultimately overcome, but considerable pain is produced. The contraction is constant. In spastic paraplegia the spasm is equal throughout the limb, or even greater at the proximal extremity. The effect is to fix both legs to the pelvis, so that if one is lifted the other is moved with it. The spasm is variable; at times it is slight, at others violent. It is excited by peripheral irritation. It is not only extensor in character, but is almost exclusively extensor. When the limbs are flexed they are supple, but as soon as they are extended they become rigid. If the ankle-joint is in extension, it is in consequence of actual shortening of the calf-muscles, which cannot be overcome. A clonus is usually obtained without difficulty, and is uniform. It is best obtained when the spasm is least. In hysterical contracture the clonus is usually variable, and best marked when the contracture is greatest. The attacks of so-called "spinal epilepsy," first tonic and then clonic spasm, excited by peripheral impressions, occur only in organic disease.

Hysterical symptoms are notoriously greatest when the patient is under examination. The patient walks best when she is unaware that she is being watched. The more attention is paid to a given symptom, by the patient or others, the greater it is. Under the influence of a strong motive, actions can be performed that cannot be effected by a simple volitional effort. Strong faradization, for instance, may make an hysterical patient move her leg when she cannot be made to move it by a voluntary effort. Care must be taken, however, not to mistake a reflex for a voluntary movement. Such a mistake frequently leads to error in diagnosis. In many cases of paraplegia, from disease of the dorsal cord, with entire loss of voluntary movement, a painful cutaneous impression will cause a flexion of the hip-joint, by which the leg is drawn up, closely resembling a voluntary movement. The observer must satisfy himself as to the character of the movement before he allows it to influence his diagnosis.

Other forms of so-called "functional paraplegia" are rare. Their most frequent causes are sexual excess and some morbid blood state, especially chronic alcoholism and gout. The loss of power is never absolute, rarely such as to prevent the patient walking, and varies from time to time. The legs "feel heavy;" they are readily fatigued, and are often the seat of abnormal sensations, tingling, formication, and the like. Sensation, reflex action, and myotatic irritability are all normal. The symptoms occur chiefly in adults and in males. The absence of indications of organic disease, the variations in the symptoms, and the recognition of the cause, usually render an accurate diagnosis practicable.

VI.—ILLUSTRATIONS OF DIAGNOSIS.

The following illustrations may render clearer the application of the methods of diagnosis. I will take, first, two cases in which the pathological diagnosis presented no difficulty, since both were cases of fractured spine, and complete paralysis of the legs occurred immediately on the accident, indicating direct damage to the cord by the displaced bone.

(1.) In the one case, that of a sailor, there was no irregularity of the spines to guide us as to the position of the injury, but this was clear enough from the symptoms. The legs were completely paralysed, and all the muscles, when the patient came under observation, some months after the injury, were greatly wasted, faradaic irritability being extinct. This proved complete degeneration of the motor nerves arising from the lumbar enlargement. Sores had formed on the limbs and sacrum, indicating damage to the nerves which influence the nutrition of the skin. Sensation was at first lost, but afterwards returned as hyperæsthesia—suggesting initial damage and partial recovery of the nerves or tracts conveying sensation. The sphincters were powerless, and their condition was such as to indicate damage to, or separation from, their centres in the cord (see p. 44). From these symptoms we inferred damage by compression of the lower part of the lumbar enlargement, and of the nerves passing it. But what was the state of the dorsal region of the cord? Sensation above the groins was normal, but this does not exclude slight damage to the cord, since the impairment of sensation caused by slight damage may soon pass away. Here it was that the superficial trunk reflexes assisted us. We found that the epigastric reflex and the abdominal reflex were perfectly natural on each side, even in the lower part of the abdomen. The cremasteric reflex, however, was active on the right side, absent on the left; so that we had evidence that the dorsal cord was normal, and that the damage commenced at the 1st lumbar nerve, where the reflex loops were damaged on the left side and normal on the right, and that just below this point the damage was great. The patient died, and the autopsy revealed exactly the condition which had been diagnosed. The dorsal cord was uninjured, and so was the highest part of the lumbar enlargement; while its lower portion was split in two by a fracture, with displacement, of the 1st lumbar vertebra, which had also compressed the nerve-roots. Microscopical examination revealed, also, slighter mischief in the cord, extending as far as the upper part of the lumbar enlargement.

(2.) The other case is that of a girl, a patient in

University College Hospital under the care of Mr. Heath. She fell off a house-top and became at once paraplegic. There were indications of damage to the bones about the 10th dorsal vertebra. The legs were completely paralysed; but there was only slight wasting, the faradaic irritability of the muscles being preserved, although lowered; and reflex action was preserved. Hence it was inferred that the motor nerves were undegenerated, that the lumbar anterior cornua were not directly damaged, that the reflex loops were entire; in short, that the damage to the cord was at or above the highest part of the lumbar enlargement. There was loss of sensibility to pain in the legs, that to touch being perfect. Hence we inferred that the destruction of the cord was incomplete. This loss extended as high as the epigastrium—evidence of some damage to the cord as high as the origin of the 8th dorsal nerves. This was corroborated by the condition of the superficial reflexes of the trunk: the abdominal was lost on both sides; the epigastric was lost on the right side, but present on the left, indicating clearly the highest level of damage. Thus there was evidence of affection of the cord from the origin of the 8th to that of the 11th dorsal pairs; but the symptoms did not show whether the damage was equal throughout this region. This information was, however, supplied by an examination of the faradaic irritability of the abdominal muscles. Above the umbilicus there was normal irritability; below the umbilicus it was gone—*i.e.*, the motor fibres of the 9th pair were undegenerated, their anterior cornua were undamaged, the fibres of the 10th pair, perhaps also the 11th pair, were degenerated, and the corresponding cornua probably damaged. As the lumbar enlargement was not directly damaged, we were able thus to limit with precision the considerable damage to the cord to the origin of the 10th, or 10th and 11th pairs. The loss of the epigastric reflex on the right side indicated that the damage to the cord on that side was greater than on the left. The subsequent progress of the case showed the significance of these indications. A month later the epigastric reflex returned on the right side, an indication of commencing recovery in the upper part of the damaged region. A few weeks later she gained some power of moving the left leg, but the reflex action became excessive in both legs, and the foot-clonus could be obtained. Now, four months after the injury, the abdominal reflexes are returning; a slight reflex can be obtained just above the groin, and above the umbilicus; none at or just below the umbilicus.*

In both these cases, thus, the information conveyed by the trunk reflexes was most important.

(3.) A man, aged twenty-eight, had suffered from weakness of the legs for more than two years. He was able to walk leaning forwards upon his sticks. His arms were unaffected. He could just flex the hips and extend the knees, but could not flex the knees, and scarcely the ankles. The right leg was the weaker. The legs were well nourished. Even as he entered the room, the clonic spasm at the ankle-joint, as the calf-muscles were put on the stretch, was conspicuous, and it was found that the knee-jerk was in great excess, and the foot-clonus could be obtained by the slightest pressure against the soles. A slight peripheral impression caused rigid spasm succeeded by clonic contraction as the stronger spasm passed lessened (spinal epilepsy, see p. 51). Thus the loss of power showed interruption to the motor path somewhere below the cervical enlargement. The preservation of the myotatic contractions, and the absence of wasting in the legs, showed the integrity of the lumbar reflex loops and grey matter, while the intensification of these contractions pointed to such over-action of the reflex centres as accompanies descending degeneration in the lateral columns.

The next point was to search for any evidence of mischief beyond the motor tract. This was found in the fact that sensation to pain in the legs was perverted: the pain of a prick was felt, but in an abnormal manner. Sensation to touch was normal. Thus it was evident that somewhere the sensory tract also was interfered with to a slight degree. The same fact was indicated by a sense of constriction around the abdomen. The two symptoms pointed to a lesion extending beyond the motor tracts, *i.e.*, to a focal lesion, and the fact that the sense of constriction was around the lower part of the abdomen made it probable that the lesion was in the lower part of the dorsal region. The cutaneous reflexes of the trunk were then examined. On the left side the epigastric reflex and the abdominal reflex above the umbilicus were very active. Just below the level of the umbilicus the abdominal reflex was much lessened, and midway between the umbilicus and groin could not be obtained. On approaching Poupart's ligament it was again produced, and an impression here caused reflex flexion of the hip. Behind, the left dorsal reflex was active, the lumbar absent. On the right side, however, the abdominal reflex was extremely slight throughout, and the epigastric reflex could not be produced (although so active on the left side), and no lower dorsal or lumbar reflex was obtainable. Thus the reflex phenomena pointed to a very limited lesion on the left side, at the level of origin of the 11th dorsal nerve, while on the right side the more extensive loss indicated more extensive mischief in the right half of the lower dorsal cord, corresponding to the greater weakness of the right leg. This affection of the reflex in the left side corresponded to the position of the constricting band around the lower part of the abdomen. What was the nature of the lesion? Its onset was very gradual; the commencement was by a sensation of "numbness," followed, eight months later, by weakness. This extreme slowness pointed to degenerative changes —local "sclerosis." There was no bone disease, no history of syphilis; but the patient had been much exposed to wet two months before the onset, and we have seen that degenerative changes sometimes result from this cause.

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* Fifteen months after the accident, the left leg has regained considerable power: the right remains paralysed. The muscle-reflex irritability has increased to spasm.

(4.) A man, aged forty-eight, came under treatment for weakness of the right leg, chiefly marked in the movements of the foot. The corresponding arm was unaffected. Thus there was impairment of the motor conducting tract (lateral column) on the right side, somewhere below the cervical enlargement. Sensation was unimpaired; the sensory tract, therefore, undamaged. The nutrition of the legs was good; the plantar reflex ready and equal; the knee-jerk excessive in each leg; the foot-clonus and front-tap contraction obtainable in each. Hence the reflex loops and grey matter of the chief part of the lumbar enlargement were intact; the excess showed that there was probably lateral sclerosis descending from a lesion above, and that this existed on the left side as well as on the right. The lesion was thus evidently somewhere in the dorsal region of the cord. To learn its seat further, the higher superficial reflexes were examined. The cremaster reflex was distinct on the left side, not to be obtained on the right. The abdominal reflex was normal on the left side, but on the right it could not be obtained except just below the edge of the ribs. The epigastric reflex, excited from the side of the chest, was distinct on each side—as readily excited on the right side as on the left. Hence we had evidence, from the impairment of the reflex loops, that the cord was damaged on the right side, from the 8th dorsal nerve to the 1st lumbar. The excess of the myotatic irritability in the left leg suggests that the mischief had implicated slightly the left half of the cord, so as to lead to some descending degeneration, although not to any loss of the cutaneous reflexes. It is possible, however, that the descending degeneration in the left side of the lumbar enlargement, may have been due to the damage of fibres of the direct pyramidal tract on the right side, before their decussation to the left side.

So much for the anatomical diagnosis. The affection had come on acutely. In nine hours from the first symptom the leg was powerless, and it was five months before it recovered. The "acute" onset points to either a vascular lesion or inflammation. Causal indications were obscure. The man attributed his symptoms to a severe strain three days before, which he stated also caused "ulcerated bowels." The wide extent of the lesion in the right side of the cord, and its acute but not instantaneous onset, suggests the probability of a myelitis, not severe in degree, although acute in onset, rather than of hæmorrhage.

(5.) A young man, aged twenty-two, presented himself with weakness, wasting, and deformity of the left forearm. The muscles of the shoulder were normal. The upper arm muscles were rather smaller than those of the right side, but were of fair size and nutrition. The muscles of the forearm were greatly wasted, except the radial extensor of the wrist; the muscles of the thumb and little finger were much wasted, the interossei only slightly. The wasted muscles had lost faradaic and voltaic irritability, the condition being of long standing, and the muscular fibres probably totally degenerated. Sensation was perfect. The leg was not quite so strong as the other; nutrition normal; the myotatic irritability excessive in each leg; knee-jerk increased, and foot-clonus and front-tap contraction obtainable. Thus we had evidence, from the muscular wasting, of a limited lesion in the left anterior cornu in the lower part of the cervical enlargement; from the impaired power in the leg, of slight damage to the motor tract for the leg; and from the excess of the myotatic contractions, of degeneration in the pyramidal tracts descending from above.

What was the nature of the lesion? Its onset was sudden, nine years before. One morning he suddenly felt a pain in the back of his neck, then he found his arms and legs becoming weak, and this increased so rapidly, that in half an hour or so he was unable to move any limb, but there was no noticeable loss of sensation. Thus he lay for three weeks, and then the right arm began to regain power, next the right leg, and then the left leg, so that in two months he could walk. The wasting in the muscles of the left arm was very rapid. There was no causal indication. Thus there was a lesion of sudden onset, and therefore primarily vascular—thrombosis or hæmorrhage—at first affecting a wide transverse area of the cord, and impairing all its functions at the spot, except conduction of sensation. The part slightly damaged soon recovered, but there remained an area of considerable damage in the left anterior cornu, and of slighter damage in the adjacent conducting tract to the leg. The focus of disease was no doubt the seat of the primary lesion; probably a local extravasation interfering with the opposite side of the cord by pressure.

(6.) The following case is somewhat complex in its indications, but is instructive as affording an illustration of the diagnosis of chronic meningitis. For an opportunity of seeing the patient, I am indebted to Dr. Russell, of Birmingham.

A man, aged forty-seven, complained of weakness of the legs, which was found, on examination, to be of irregular distribution. In both legs the muscles moving the hip-joint possessed good power. The flexors and extensors of the knee-joint were strong in the right, but very weak in the left leg. The flexors of the ankle in the left leg were rather weak, in the right were powerless; the extensors of the ankle were weak in both legs, but much weaker in the right than in the left. The muscles were wasted, and had lost faradaic irritability in proportion to their weakness, the voltaic irritability being preserved. The wasting was greatest in the extensors of the left knee, and flexors of the right ankle. In the latter faradaic irritability was gone. Sensation was normal, except in an area in the front of the left leg, where it was absolutely lost to both touch and pain. Plantar reflex normal; no foot-clonus; knee-jerk slight in the right leg, absent in the left.

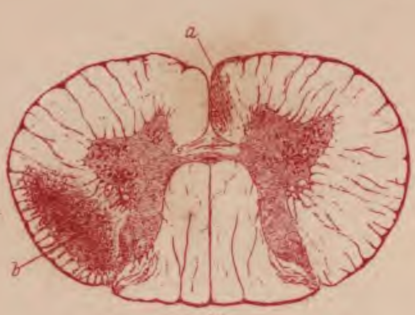
The affection of nutrition and electrical irritability indicated disease in the anterior cornua, or in the motor nerves springing from them. By this the impairment of the knee-jerk was also explained. The weakness was in proportion to the wasting; hence there was no reason to infer other disease than that interfering with nutrition. The diagnosis thus lay between a primary cornual disease, and damage to the nerve-roots by meningeal changes. The patch of anæsthesia in the left leg was in favour of the latter. It is rare that anterior cornual disease impairs sensation.

The mode of onset was then investigated to ascertain what light the order of the symptoms would throw on the seat, and their rapidity of development on the nature of the disease. The first symptoms commenced nine months before, and were sensory; soreness in the left leg, followed by shooting pains, sometimes in the big toe, sometimes in the calf, but confined to the left leg; these lasted for two months, and during that time the leg gradually got weak. After this similar pains were felt in the right leg, and this also became weak.

Pains of this darting character are usually due to irritation of the sensory nerve-roots; they are similar to those met with in locomotor ataxy, and are almost unknown in affections of the anterior cornua. These pains, in conjunction with the patch of anæsthesia, rendered it highly probable that the mischief was outside the cord in the meninges—chronic meningitis with thickening, the nerve-roots being irregularly damaged by irritation and compression. Hence a careful search was made to ascertain if there were any trunk symptoms, throwing light on the disease. Inquiry elicited a history of shooting pains on the right side of the trunk, at the level of the epigastrium, with a unilateral sense of constriction. Some local hyperæsthesia was found, but no anæsthesia. This also pointed to local irritation of the posterior nerve-roots, higher up —to irregular meningeal irritation.

The causal influences were then ascertained. No immediate cause could be ascribed except general bad health. Chronic meningitis is most frequently due to bone disease or syphilis. There was no evidence of bone disease, but the patient had had a chancre twenty years before.

Thus the motor symptoms indicated either cornual or meningeal disease; the sensory symptoms pointed strongly to the latter, and the causal conditions, as far as they went, harmonized with the view. (The patient had had some sugar in the urine, which, except for rendering the prognosis worse, had little apparent bearing on the case.) He had taken iodide for a time, but without improvement. This did not, however, militate against the diagnosis for the following reason:—The meningeal change, though probably syphilitic, had caused damage to the nerves, which, descending as degeneration, had led to secondary changes in the muscles. The removal of the syphilitic change in the membranes would not at once restore the nerves. Their regeneration, if still possible, would be, of necessity, a work of time, perhaps of more time than had yet been allowed. Hence the patient was urged to persevere with the iodide, and mercury was added to it, and he was advised to continue the use of a voltaic battery to the muscles. A month later there was slight but distinct increase of power in the left thigh. I did not see him again, but a year later he was seen, incidentally, by Dr. Russell, who has been good enough to inform me that the man then said he was, and appeared to be, perfectly well. The result thus affords a strong confirmation of the diagnosis.



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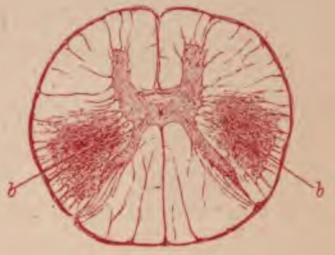

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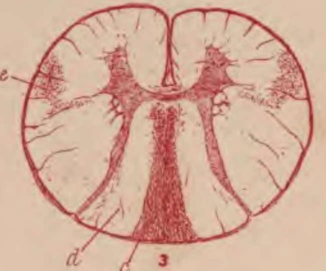

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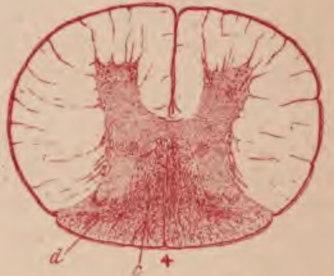

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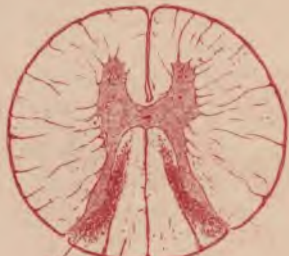

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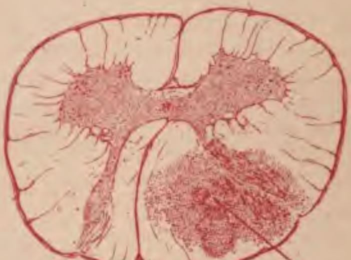

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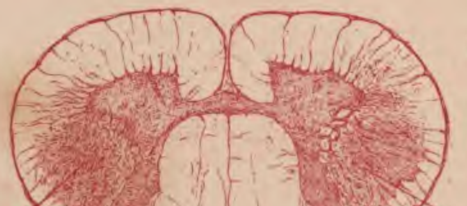

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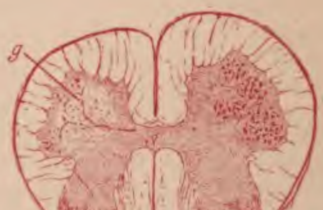

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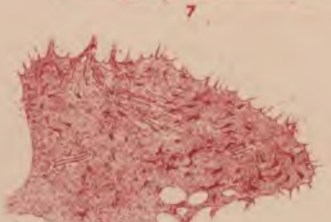

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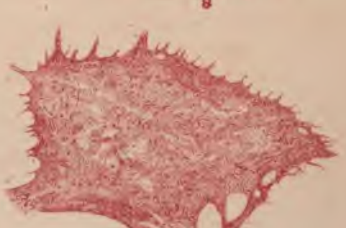

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DESCRIPTION OF PLATE.

THE figures represent some of the more important lesions of the spinal cord. Although semi-diagrammatic, they have, with one exception, been drawn, with care, from actual sections. The exception is Fig. 2, which is after Charcot. It may be well to state, for the information of those unfamiliar with the process of microscopical examination of the nerve-centres, that when a section of the spinal cord is stained with carmine, the tint assumed by the different parts varies, and conveys important information. The grey substance stains much more deeply than the white, and the nerve-cells more deeply than the inter-cellular grey substance. Hence the grey matter appears like an H-shaped rose-coloured area, in which the nerve-cells appear of a much deeper red. The white substance of the nerve-fibres does not stain, and although the axis-cylinders stain, they are not sufficient in bulk to give much colour to the white columns. Connective tissue, however, stains very deeply, and the edge of the section (pia mater) is thus deep red, and so are the trabeculæ of connective tissue which extend into the white substance. Since the process of sclerosis consists in an atrophy of the nerve-fibres, and an increase in the connective tissue, areas so affected stain deeply in proportion to the intensity of the change, and its existence and degree may thus be rendered conspicuous even to the naked eye. The relative tint of the figures is nearly that of the sections from which they were drawn, all of which were stained with carmine. The letters indicating corresponding parts are the same in all the figures.

FIG. 1. *Descending Degeneration, unilateral.*—Section of spinal cord, cervical region, from a case of left hemiplegia due to disease of the right cerebral hemisphere. The two pyramidal tracts are degenerated, viz., the small "anterior pyramidal tract" (*a*), close to the anterior median fissure, on the right side of the cord; and the "lateral pyramidal tract" (*b*) in the opposite lateral column. This degenerated tract is seen not to extend up to the surface, being bounded by the so-called "cerebellar tract." (See p. 10.)

FIG. 2. *Descending Degeneration, bilateral.*—Section of spinal cord, dorsal region, below a point damaged by compression. Both lateral pyramidal tracts (*bb*) are degenerated. There is no degeneration in the anterior pyramidal tracts, which had probably ceased (by decussation) above the level of the section, or may have been absent.

FIG. 3. *Ascending Degeneration.*—Section of spinal cord in dorsal region, from a case in which the lower extremity of the cord was crushed

by a fracture of the spine. The postero-median columns (*c*) are densely sclerosed. The postero-external columns (*d*) are quite free from sclerosis. The pyramidal tracts in the lateral columns are seen to be also free from disease (compare Figs. 2 and 3), but just in front of each is a symmetrical area of slight degeneration (*e*). (See p. 12.)

FIG. 4. *Posterior Sclerosis, Locomotor Ataxy.*—Section at the level of the first lumbar nerves. The posterior columns are densely sclerosed throughout their entire extent. The remaining white columns and anterior cornua are healthy.

FIG. 5. *Sclerosis of Postero-external Column* (*posterior root-zone*), *Locomotor Ataxy* (from a section prepared by Prof. Pierret, of Lyons).—A dense band of sclerosis occupies the postero-external column (*d*), through which the posterior nerve-roots pass. The postero-median columns (*c*) are free from sclerosis. The bands of sclerosis are narrow, probably from the contraction of the tissue, since, from the position of the limiting septum, they appear to occupy the entire width of this column. The patient suffered from well-marked locomotor ataxy.

FIG. 6. *Syphilitic Growth in Posterior Column.*—Section through the spinal cord, cervical region, of a man who died from syphilitic disease of the brain. A growth (*f*) occupies the right postero-external column, and has enlarged it to three times the normal size, displacing the posterior median septum to the left. The growth has invaded the right posterior cornu, and extended a little way beyond it into the lateral column. It caused inco-ordination, and partial loss of sensibility, in the right arm.

FIG. 7. *Anterior Cornual Degeneration.*—Section of spinal cord, cervical region, from a patient suffering from progressive muscular atrophy. The grey substance of the anterior cornua is degenerated and irregularly translucent, the nerve-cells having disappeared (compare also Figs. 9 and 10). The lateral columns (pyramidal tracts) are also sclerosed. The posterior columns are healthy.

FIG. 8. *Anterior Cornual Myelitis* (*Infantile Paralysis*).—Section of spinal cord, lumbar enlargement, from a case of old infantile paralysis of the left leg. The whole left half of the cord is smaller than the right. The left anterior cornu is shrunken, and presents evidence of previous inflammation. The tissue is degenerated and translucent, containing large vessels. All the motor nerve-cells, so conspicuous on the other side, have disappeared.

FIG. 9.—Normal anterior cornu, cervical region, showing numerous multipolar nerve-cells.

FIG 10.—Anterior cornu, same position, from a case of progressive muscular atrophy. All the nerve-cells have disappeared; minute shrunken corpuscles here and there are probably their remains. The grey matrix, instead of being uniform, is irregular, translucent at some spots, unduly dense, from sclerosis, at others, especially near the edge of the cornu.

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